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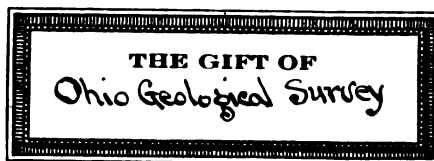
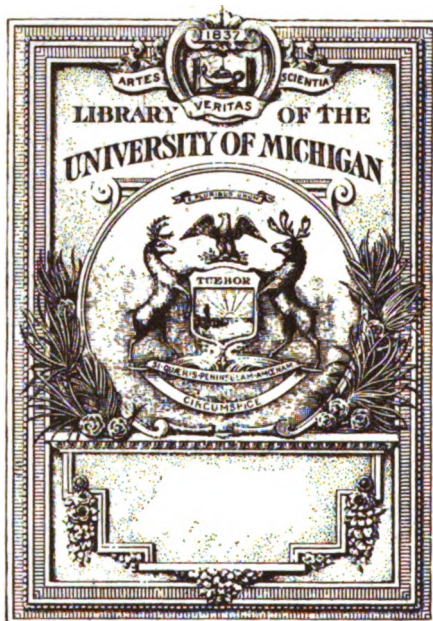
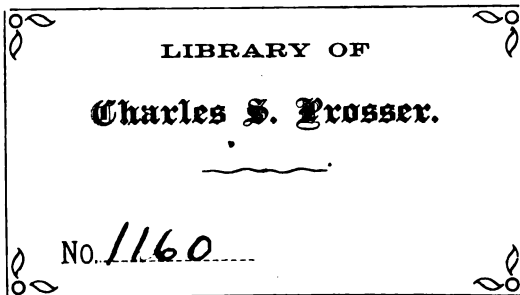
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GEOLOGICAL SURVEY OF OHIO

J. A. BOWNOCKER, State Geologist

FOURTH SERIES, BULLETIN 14

IN COOPERATION WITH THE UNITED STATES GEOLOGICAL SURVEY

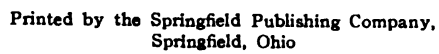


**GEOLOGY OF THE
COLUMBUS QUADRANGLE**

**By CLINTON R. STAUFFER, GEORGE D. HUBBARD
and J. A. BOWNOCKER**

**COLUMBUS OHIO
1911**

11



TO GOVERNOR JUDSON HARMON:

Dear Sir—I transmit herewith the manuscript for Bulletin 14, Geological Survey of Ohio, entitled Geology of the Columbus Quadrangle. The work was done conjointly by Dr. Clinton R. Stauffer of Cleveland, Dr. George D. Hubbard of Oberlin and J. A. Bownocker of Columbus.

The Bulletin has been prepared for the hundreds of students who are getting their first ideas of Geology, and for the general reader. For this reason it is free from many of the technicalities that usually appear in Geological reports. The excellent maps that accompany the work have been prepared by the United States Geological Survey in cooperation with the Geological Survey of Ohio. By this arrangement the expense to Ohio has been greatly reduced.

Many of the facts included in the Bulletin have appeared in earlier publications of the Survey, but since these have long been out of print it has appeared best to issue a new publication which should record the progress made to the present time.

Respectfully submitted,

J. A. BOWNOCKER,
State Geologist.

Columbus, Ohio, November 1, 1911.

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THE SURVEY IN ITS RELATIONS TO THE PUBLIC.

The usefulness of the Survey is not limited to the preparation of formal reports on important topics. There is a constant and insistent desire on the part of the people to use it as a technical bureau for free advice in all matters affecting the geology or mineral industries of the State. A very considerable correspondence comes in, increasing rather than decreasing in amount, and asking specific and particular questions on points in local geology.

The volume of this correspondence has made it necessary to adopt a uniform method of dealing with these requests. Not all of them can be granted, but some can and should be answered. There is a certain element of justice in the people demanding such information, from the fact that the geological reports issued in former years were not so distributed as to make them accessible to the average man or community today. The cases commonly covered by correspondence may be classified as follows:

1st. Requests for information covered by previous publications—This is furnished where the time required for copying the answer is not too large. Where the portion desired cannot be copied, the enquirer is told in what volume and page it occurs and advised how to proceed to get access to a copy of the report.

2d. Requests for identification of minerals and fossils—This is done, where possible. As a rule, the minerals and fossils are simple and familiar forms, which can be answered at once. In occasional cases, a critical knowledge is required and time for investigation is necessary. Each assistant is expected to co-operate with the State Geologist in answering inquiries concerning his field.

3d. Requests from private individuals for analyses of minerals and ores, and tests to establish their commercial value.—Such requests are frequent. They cannot be granted, however, except in rare instances. Such work should be sent to a commercial chemical laboratory. The position has been taken that the Geological Survey is in no sense a chemical laboratory and testing station, to which the people may turn for free analytical work. Whatever work of this sort is done, is done on the initiative of the Survey and not at the solicitation of an interested party.

The greatest misapprehension in the public mind regarding the Survey is on this point. Requests for State aid in determining the value of

private mineral resources, ranging from an assay worth a dollar, up to drilling a test well costing several thousand dollars, represent extreme cases. At present there is no warrant for the Survey making private tests, even where the applicant is entirely willing to pay for the service. In many cases individuals would prefer the report of a State chemist or State geologist to that of any private expert, at equal cost, because of the prestige which such a report would carry. But it is a matter of doubt whether it will ever be the function of the Survey to enter into commercial work of this character; it certainly will not be unless explicit legal provisions for it are made.

4th. Requests from a number of persons representing a diversity of interests, who jointly ask the Survey to examine into and publicly report upon some matter of local public concern.—Such cases are not common. It is not always easy to determine whether such propositions are really actuated by public interest or not. Each case must be judged on its merits. The Survey will often be prevented from taking up such investigations by the lack of available funds, while otherwise the work would be attempted.

The reputed discovery of gold is one of the most prolific sources of such calls for State examinations. It usually seems wise and proper to spend a small sum in preventing an unfounded rumor from gaining acceptance in the public mind, before it leads to large losses, and unnecessary excitement. The duty of dispelling illusions of this sort cannot be considered an agreeable part of the work of the Survey, but it is nevertheless of very direct benefit to the people of the State.

PUBLICATIONS OF FOURTH ORGANIZATION, GEOLOGICAL SURVEY OF OHIO.

Under the law, copies of these Bulletins can be bought at the office of the State Geologist at the cost of publication. Postal orders, money orders, checks, drafts or currency must accompany orders. *Stamps will not be received.*

Bulletin 1. Oil and Gas. (325 pages; 1903.) By J. A. Bownocker.

The Oil and Gas Producing Rocks of Ohio, The Trenton Limestone as a Source of Oil and Gas. The Clinton Formation as a Source of Oil and Gas. The Carboniferous Rocks as a Source of Oil and Gas. The Origin of Oil and Gas and the Conditions under which they are found.

Contains nine lithograph maps showing oil and gas fields.

Price.....65 cents.

Bulletin 2. Uses of Hydraulic Cement. (260 pages; 1904.) By Frank H. Eno.

A Brief History of Cement. The Use of Cement in Mortars. The Uses of Cement in Concrete. The Uses of Cement in Reinforced Concrete. Specifications for Concrete Materials. Machinery and Tools.

With 157 illustrations.

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Bulletin 3¹. Manufacture of Hydraulic Cement. (391 pages; 1904.) By A. V. Bleining.

General Considerations on the Hydraulic Cements. Raw Materials of the Cement Industry. Analysis and Testing of the Raw Materials. Manufacture of Pozzuolani and Natural Cements. On the Nature of Portland Cement. The Compounding of Portland Cement Mixtures. Mining and Preparation of the Raw Materials. The Burning of Portland Cement. The Grinding of the Clinker and General Arrangements of Plants. The Properties of Portland Cement and the Testing of Cement.

With 81 illustrations.

Price.....75 cents.

Bulletin 4². The Lime Resources and the Lime Industry in Ohio. (361 pages; 1906.) By Edward Orton, Jr., and Samuel V. Peppel.

The Occurrence, Extent and Economic Classification of the Limestones of Ohio. Methods Employed in Sampling and Testing Limestones. The Composition of the Limestones of Ohio, with Special Reference to their Fitness for Portland Cement Manufacture, Considered by Counties. The Composition, Physical Character, and Uses of the Limestones of Ohio, Considered by Geological Formations. The Uses of Limestones of Ohio. Technology of the Lime Industry.

With 53 illustrations.

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Bulletin 5³. The Manufacture of Artificial Sandstone or Sand-Lime Brick. (70 pages; 1905.) By Samuel V. Peppel.

History and Description of the Industry. The Raw Materials, their Impurities and their Preparation. The Pressing and Hardening. Testing. Properties of the Product. Mechanical Equipment for Manufacture. Processes and Patents.

With 8 illustrations.

Price.....45 cents.

Bulletin 6. A Bibliography of Ohio Geology. (332 pages; 1906.)

Part I. A Subject Index of the Publications of the Geological Survey of Ohio, from its Inception to and including Bulletin Eight of the Fourth Series. By Alice Greenwood Derby.

¹Sale edition exhausted.

²Bulletins 4 and 5 are bound together.

Part II. A Bibliography of the Publications relating to the Geology of Ohio, other than those of the State Geological Survey. By Mary Wilson Prosser.

Price.....35 cents.

Bulletin 7. Revised Nomenclature of the Ohio Geological Formations. (36 pages; 1905.) By Charles S. Prosser.

Price.....6 cents.

Bulletin 8. Salt Deposits and the Salt Industry in Ohio. (42 pages; 1906.) By J. A. Bownocker.

Price.....6 cents.

Bulletin 9. Coal. (342 pages; 1908.) By J. A. Bownocker, N. W. Lord and E. E. Somermeier.

Part I. The Pittsburg Coal; The Pomeroy Coal; The Meigs Creek Coal.

Part II. Chemical Analyses and Calorific Tests of the Clarion, Lower Kittanning, Middle Kittanning and Upper Freeport Coals.

With two maps showing Meigs Creek, Pomeroy and Pittsburg Coals.

Price.....50 cents.

A New Geological Map of Ohio. (1909.) By J. A. Bownocker.

Showing in colors the larger geological formations of the State, also the glacial boundary and shore of glacial Lake Erie. Of special interest are the economic features showing (1) oil and gas producing areas, (2) railroad and river shipping coal mines, (3) portland cement works, (4) salt works, and (5) gypsum mines.

Price.. ..25 cents.

Bulletin 10. The Middle Devonian in Ohio. (204 pages; 1909.) By Clinton R. Stauffer.

General Discussion of the Middle Devonian. Discussion of Sections and Faunas. The Relationships of the Middle Devonian of Ohio. Notes on and Descriptions of Species.

Price.....25 cents.

Bulletin 11. The Manufacture of Roofing Tiles. (476 pages; 1910.) By W. G. Worcester with the Cooperation of Edward Orton, Jr.

Brief History of Roofing Tile Manufacture and Use. The Varieties and Qualities of Roofing Tiles. The Selection of Clays for Roofing Tile Manufacture. The Preparation of Roofing Tile Clays for Manufacture. The Manufacture or Forming of Roofing Tiles from the Prepared Clay. The Manufacture of Special Shapes and Roofing Terra Cotta. The Drying of Roofing Tiles. The Setting of Roofing Tiles. The Kilns for Burning Roofing Tiles. Roofing Tile Slips and Glazes. Stocking and Shipping Roofing Tiles. Location and Design of Plants for Roofing Tile Manufacture.

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Bulletin 12. The Bremen Oil Field. (67 pages; 1910.) By J. A. Bownocker.

The Bremen Oil Field. The Search for Oil in the Clinton Sand North of the Bremen Field. The Search for Oil in the Clinton Sand South of the Bremen Field. Contains colored map of Bremen Field and 3 sections showing structure of Clinton sand.

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Contains five plates and six figures.

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FOURTH SERIES, BULLETIN 14

IN COOPERATION WITH THE UNITED STATES GEOLOGICAL SURVEY

**GEOLOGY OF THE
COLUMBUS QUADRANGLE**

**By CLINTON R. STAUFFER, GEORGE D. HUBBARD
and J. A. BOWNOCKER**

NOVEMBER, 1911

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INTRODUCTION.

Geological surveys have usually had for their prime object the description of natural resources of a geological nature with reference to their utilization by man. This has often made necessary descriptions of fundamental facts, not of direct economic value, such as stratigraphy or rock succession, paleontology or former life, and physiography or surface features, so that the publications have had commonly a wide scope.

Thus far but little has been done by surveys for direct use in colleges and high schools. Illustrations and descriptions in text-books are usually from distant points, with the result that scant information is available to instructors and students of the geology of their own communities.

This bulletin is intended to meet such wants. It is designed for students in colleges who are taking their first course in geology and for teachers in high schools. It is hoped that it will be of service also to those citizens who desire information in concise form of the rocks around them, but who cannot readily follow the usual geological publications. Effort has been made to free this bulletin from technicalities, but in doing this accuracy has not been sacrificed.

The maps which form so valuable a part of the bulletin were prepared by Professors Stauffer and Hubbard, the former the one showing the Areal Geology and the latter the Physiography. The engraving and printing were by the United States Geological Survey.

PART I

HISTORICAL OR AREAL GEOLOGY.¹

By CLINTON R. STAUFFER

CHAPTER I

INTRODUCTION.

Geology is merely a history of the Earth. In other words, it is the study of Nature in its broadest sense. Since we are all a part of Nature and are subject to its laws on every hand, the science of Geology touches our very existence from its beginning to its end. More than that, it reaches far back into the past and grapples with the question of the origin of the Solar System, but more especially of the Earth, long before the germ of life had been brought into existence, and turns to the future with the same determination to wrest from it the secrets of that which lies in store for our planet. It is the broadest of the sciences and is the foundation on which many of our industrial pursuits are built. A lack of knowledge of even the most obvious principles of Geology, and a wanton neglect of those which we really do know, have cost mankind a very considerable amount of money and many lives. We are thus brought to a realization of the importance of the subject before us.

It is hardly to be expected that many people have or will acquire an intimate knowledge of Geology. Yet it seems eminently desirable that everyone should know something about the history of the material, which composes the more enduring part of our State, and have a more particular knowledge of the lakes, rivers, soil and rocks of his immediate surroundings. Certainly no science is easier to acquire and few will give more pleasure than the ability to read from the solid rock the history of the material which so often passes unnoticed under our feet.

Rocks of all kinds which are exposed to the action of the atmosphere, its varying temperature and humidity, gradually disintegrate. The bare rock surface heats rapidly under the action of the sun's rays. This heating causes an expansion of the outer portion or shell. Since rock is a poor conductor of heat, the change in temperature penetrates but slowly and the outer portion, expanding more rapidly than the inner, is fractured or broken loose from the cooler part within. When the rocks are once thoroughly heated and then rather suddenly cooled at the surface a process, which is the reverse of that just outlined, sets in

¹ The portion pertaining to the southern half of the Columbus quadrangle is based on work done by Dr. Prosser and Dr. Cumings; however, in many instances the writer has drawn on his own knowledge of the field.

and again the result is fracturing of the rock. If the cracks in the rocks are filled with water and the change in temperature cools it below 32° F., then the water freezes and the expansion (about one-tenth) resulting therefrom disrupts the rock. Also oxygen, carbon dioxide and water penetrate the crevices and pores of the rock and become a part of its chemical composition. This addition of material means an increase of volume (in granites as high as 80%) and consequently a disruption of the mass, for not all parts are equally affected. Some of these new chemical compounds are soluble in water, especially if it contains organic acids, and hence may be leached out and carried away by ground water. In cases of sandstone, the mineral matter which binds the sand grains together is often soluble and, if dissolved out by ground water, leaves only a bed of sand.

These disintegrating processes are at work not only in the rocks which are actually at the surface, but also in those at some distance below, for the loose outer portion of the surface material is penetrated by the atmosphere while ground water may carry the active chemical agents to a considerable depth and there work changes similar to those which take place at the surface.

So the bed rock, which happens to be near the surface of a land area, is gradually changing into the loose material which we are accustomed to see everywhere. This loose earth, composed of the disintegrated bed rock, is called the mantle rock because it forms a mantle which covers the bed rock more or less completely. Normally the mantle rock, when penetrated from the surface downward, contains larger and larger fragments of rock until finally it grades into the bed rock below. In regions which have been recently glaciated, however, the upper surface of the bed rock is smoothed and striated and the contact between it and the mantle rock is sharp. Such is the case in the Columbus region and will be discussed in Part II.

But if the bed rock is gradually changing to mantle rock why, we may ask, is not the latter much thicker than we find it? To answer this question it is but necessary to recall the natural processes which are working so constantly and quietly about us. Every shower leaves its impression on the surface of the land. A portion, small though it may be, of the loose earth, the mantle rock, is moved down the hillside and into the river below. Once in the river it is swept on with the current until finally it comes to rest as sediment in some great body of quiet water, such as a lake or the sea. If now one shower can move a little of the mantle rock from the hillside, what must be the effect of millions of showers?

But it is with the history of this material after it has come to rest on the bottom of the sea that we have to deal at present. These materials, such as clay, sand, gravel, etc., carried down to the sea by the rivers and deposited there, are called clastic sediments because they are

made up of broken fragments of rock. It is easily seen that not all streams are depositing the same kinds of sediment. Mountain torrents on steep coasts are likely to sweep down very coarse gravel, while on gentle plains the rivers will be sluggish and carry only the finest particles (silt) to the sea. At some localities the change from one kind of sediment to the other is gradual and one may trace the successive steps in the process with a fair degree of accuracy; at other places, however, the change is so abrupt that it forms a striking feature in the sedimentary series. Such differences have led to the division of the rocks into formations. While one kind of material is being deposited, that is, until some decided break occurs in this process of sedimentation, there is naturally a similarity of the material above and below any given point. So long as this continues, we usually call it a single formation. But after the change, whether it comes suddenly or not, a different kind of sediment is found where it did not formerly exist, that is, a new formation has begun. It has thus happened that thousands of feet of varying sediments have accumulated on the sea bottom and the process is still going on.

It is a well known fact that most river water contains lime dissolved from the soil or underlying rock. This is abundantly proved by the coating (boiler-cake) which is often so troublesome in the boilers of engines, and likewise in tea kettles. The continual transfer of this material from the land to the sea must eventually contribute a large amount of lime to the waters of that body. The penetration of the sediments by this lime-laden water, together with the pressure of the overlying material, often cements them into solid rock. Iron and silica sometimes perform the same function. Still other portions of the lime in ocean waters are extracted by marine organisms, such as corals and clams, whose shells or hard parts are made up largely of Calcium carbonate—merely a different form of lime. When these animals die their skeletons are deposited on the ocean bottom and form beds which become cemented into limestone. Some limestones are thought to have originated in other ways, probably by chemical means, but the great body of the limestone deposits is doubtless of organic origin.

Sediments, whatever their origin, frequently contain the remains or traces of organisms, which lived during the time that the deposits were being formed. These remains are usually shells, bones, teeth, tracks, trails or burrows, the impressions of leaves, bark, fruits, etc., but in exceptional cases the entire organism is preserved. All of these remains or traces, which give us some knowledge of the organisms that have existed in past ages, are known as fossils.

On the modern sea shore a certain association of animals (a fauna) is found living on the sandy bottom while a very different fauna may be living on the muds of another part of the shallow waters. Since some forms of sea life are better adapted to the colder waters than

others, faunas vary with the latitude. Moreover it is known that certain species, once abundant, are dying out (becoming extinct) while others are becoming more numerous. The remains of extinct species usually show more primitive characters than are common in living species. This is still more likely to be the case when fossils from the earlier sediments are compared with those of sediments more recently deposited. Hence we may say that fossils vary with the kind of sediment being deposited and with the progress of time. Thus we have the means of classifying the sedimentary formations according to a time scale based on the contained fossils.

It has often been observed that the land and sea are not maintaining definite relations to each other. Thus, some coasts are slowly rising while others are sinking. Bladensburg and Dumfries, in the neighborhood of Washington, D. C., could be reached by sea-going ships in Colonial days, but now are decidedly above tide level.¹ A portion of the coast of Greenland has been sinking for the past four centuries. "Old buildings and islands have been submerged; and the inhabitants have had to put down new poles for their boats, the old ones standing—'as silent witnesses of the change'."² Hence great portions of the Earth's surface, which were once beneath the sea, may have been elevated to form a portion of the dry land, while others, which once were a part of the continent, may now be covered by the sea.

If we imagine the present North American land surface to sink, or the sea to rise, so that the waters of the Gulf of Mexico should extend northward and those of the Hudson Bay southward until they would meet at some point in Ohio, then conditions, somewhat similar to those which prevailed in this region while the limestones and shales were being formed, would be restored. Around the higher portions of the land, which would form islands or shoals in this sea, coral reefs would probably be built. Colonies of crinoids might flourish at other points, while the greater portion of the bottom of this shallow or epicontinental sea would probably swarm with clams, snails, crabs, lobsters and every other form of marine life which is now found along the Atlantic coast. When these animals would die their calcareous remains might form deposits of limestone. Such an abundance of life would furnish a most excellent feeding ground for fishes and it is probable that great schools of them would inhabit the region and ultimately contribute their skeletons to the deposit. At another time conditions might be so changed that so much mud would be brought down by running water that the shells of animals would contribute but a small amount to the total deposit, and a fossiliferous shale would result.

It may thus be seen that the bed rock, underneath the thin covering of glacial drift, was once deposited as sediment beneath the sea.

¹ Scott, W. B., *Introduction to Geol.* 1902, p. 67.

² Dana, J. D., *Manual of Geol.*, 4th Ed., 1895, pp. 349-350.

The shales are nothing more than the cemented beds of silt or mud, the sandstone and conglomerates cemented sands and gravels, while the limestone mainly comes of organic origin. When we remember that these sediments have been washed down from ancient hills and carried to the sea or other lodgment basin, just as material is now being transported to the ocean, and that in this process of wear and reconstruction perhaps whole continents have been involved, we must feel a keen interest in these forces and their results.

SEDIMENTARY RECORD.

The mantle of drift, spread over the Columbus quadrangle, is quite irregular in thickness. In the northern part of the city, shale lies



Fig. 1—A small anticline in the Delaware limestone along the east bank of the Olentangy River, below Stratford.

within a few inches of the surface while three miles west of Dublin well-drillers report two hundred feet of glacial drift. Over the greater part of the area, however, bed rock lies so near the surface that it outcrops along even the minor streams.

The outcrops of the various formations, which constitute the rock floor of the section under consideration, are essentially parallel and extend in a northerly and southerly direction. The dip (inclination from the horizontal) of these formations is to the eastward and runs

from twenty to about thirty feet per mile. Such a slight variation from the horizontal is observable only when the elevations of distant outcrops of the same bed are compared. However the strata are frequently so affected by small folds that the dip is temporarily reversed. Some of these little folds may be found along the Olentangy River, south of Stratford, where the Delaware limestone is folded into well developed anticlines and synclines with axes extending nearly east and west (see Figure 1). Other disturbed strata may be seen in the Bedford shale along Rocky Fork northeast of Gahanna (see Plate V).

In composition the formations, in stratigraphic succession from west to east, bear an interesting relation to each other. Every gradation from the pure limestone to the quartz conglomerate is to be found within the short space of twenty miles. Just what this means is perhaps a greater problem than may at first appear. Such clastic sediments as mud, sand, gravel, etc., following each other in orderly succession (see Plate VII) after the deposition of calcareous material, seems to indicate a shallowing of the basin within which they were formed; but even if this be the chief cause, it is not clear from whence the material came. Moreover it is not strictly true that the shales, or even the sandstones and conglomerates, were necessarily formed in shallower water than that which prevailed during the deposition of the calcareous sediments. Such limestone as results from the accumulation of the hard parts of lime-secreting organisms is not always or even usually a deep sea deposit. Crinoids, corals, brachiopods, mollusks, etc., flourish in our modern seas at slight depths and often near the land. It seems probable, therefore, that factors other than change of depth were also operative. Perhaps one of these was the closing of channels by which the inland sea had maintained its communication with the open ocean. Such a change, resulting from an upward movement of the land (diastrophism), would render the waters temporarily brackish and therefore less favorable for the existence of lime-secreting organisms. More than that, any low lying tracts of land, which may have existed and which were deeply covered with weathered material due to the long period when there was relatively little erosion, would thus be brought into a position favorable for the removal of this weathered mantle by the action of running water and consequently the formation of shale would probably be initiated. While the black shale (Ohio) was being deposited, the sea must have been reduced to the condition of a swamp approaching that of the coal forming period. In fact many of the plant fragments found in this formation are highly carbonaceous, really an impure coal, and the formation itself is characteristically bituminous.

With the advent of the sandy sediments, other changes more profound must have occurred, but what they were is perhaps highly speculative. It is certain, however, that some effective means of shifting sand must have been operative, since the only plausible source of such

material was the disintegration of quartz bearing rocks in the highlands of the old land masses to the north—a long distance from its ultimate resting place.

These various sediments, including the glacial deposits, which come to the surface in the Columbus region, may be grouped together in the following classification:¹

Cenozoic	Quaternary	(Drift)	{ Wisconsin Illinoian
~~~~~ Unconformity ~~~~~			
Paleozoic	Mississippian	Waverlyan	{ Black Hand form. Cuyahoga form. Sunbury shale Berea grit Bedford shale
	Devonian	{ Chautauquan and Senecan	{ Ohio shale
		Erian	{ Olentangy shale
		Ulsterian	{ Delaware limestone Columbus limestone
	~~~~~ Unconformity ~~~~~		
	Silurian	Cayugan	Monroe form.

The presence of underlying sedimentary deposits, other than those outcropping, is known from the records of deep wells drilled in this vicinity. The most important of these are the State House well² and the well drilled on the bank of the Olentangy River in 1889. These wells penetrated between two and three thousand feet of strata and give us a section, of more or less value, extending down into the Ordovician.

OUTCROPPING FORMATIONS.

A formation is usually considered as outcropping if it is the one immediately underlying the mantle rock.

Monroe Formation.—As indicated in the above table, the lowest of the outcropping formations within this area is the Monroe formation. In the central part of the State, the Monroe is a fine grained compact drab limestone or dolomite which is rather thin bedded and has a distinctly banded structure. Sometimes the freshly fractured surface of the rock has a strong petroleum odor, but that is likely to be the case with any of the limestones of the region. It is not a very fossiliferous formation in any locality and here it is exceptionally poor in animal remains.

¹ Prosser, C. S., Geol. Surv. Ohio, 4th Ser., Bull. No. 7, 1905, p. 3.

² Newberry, J. S., Geol. Surv. Ohio, Vol. I, pt. 1, 1873, pp. 113, 114. Also Vol. VI, 1888, pp. 107, 108; 281, 282.

Occasionally, however, *Leperditia alta* and more rarely *Spirifer vanuxemi* have been found. In the northern part of the state, in Michigan and in Canada, the formation contains a considerable fauna. Many of the species found in those localities resemble so closely certain Devonian, rather than Silurian, forms that the exact age of the upper part of the limestone is more or less in doubt. The formation is limited in its surface outcrop to a rather indefinite portion of the west side of the quadrangle. Meager outcrops occur along Mill Creek as well as along Big and Little Darby Creeks, where usually about six or eight feet of rock are to be seen—a mere fraction of the total thickness of the formation.

North of Harrisburg about three miles, and just above the bend of the Big Darby, the contact between the Columbus and underlying Monroe comes to the surface. The outcrops, however, are poor and of little importance other than for the interesting boundary line which they show. Northward from here for the next two miles these limestones may frequently be seen, but never more than a small section is exposed.

The best and most accessible places for seeing the Monroe formation, as well as the Silurian-Devonian contact, are near Georgesville. On the south bank of Little Darby Creek, one mile west of its junction with the Big Darby and on land owned by Mr. E. N. Coberly, there is a very good limestone cliff where the following section was measured by Dr. Cumings:

<i>Columbus limestone.</i>	Thickness.
7. Soft crystalline brown limestone, with pockets of calcite. This rock weathers irregularly, which thus produces a conspicuous honey-combed surface. The residual soil, resulting from its decomposition, has a red color. (The best exposures of this portion of the formation are in a small run in the hillside just a little east of where the creek turns east. These layers are still better shown about 100 feet farther to the east)	7' 0"
6. Drab or yellowish limestone blotched with darker spots; often flaky and somewhat crystalline. It occurs in a single layer with a surface uneven, but not honey-combed	2' 0"
<i>Monroe formation.</i>	
5. Thin bedded, uneven, very impure, drab limestone. The upper part contains some seams of calcite, is hackle-toothed, contorted, and weathers with a honey-combed surface	3' 8"
4. More evenly bedded, very light colored, fine grained compact limestone, in three conspicuous layers, and having a clean vertical fracture	4' 0"
3. Massive, but weathering into thin irregular layers; bedding planes uneven and wavy. The lower layers are compact and very fine grained	4' 0"
2. Thin bedded, ash colored, banded limestone, which breaks with a clean vertical fracture	1' 0"
1. Massive, impure, argillaceous, magnesian limestone, with the color of ashes, and a tinge of yellow. This part of the section is usually covered with talus, but is exposed at intervals to low-water level	5' 0"

The transition from the Silurian to the Devonian here lacks one of its usual characteristics—the basal conglomerate. This consists of pebbles of the compact banded drab limestone (Monroe) imbedded in a matrix of brown Columbus limestone and forming the basal layer of the latter formation. These pebbles are well rounded and vary in size from a fraction of an inch to three or four inches in diameter. Occasionally there is some quartz sand intermingled with the pebbles and at places this is so abundant that it has been called a sandstone. The thickness of this conglomerate is usually about six inches and it rarely exceeds two feet. It is almost universally present where this contact comes to the surface in the central part of the state. One of the best places for observing the conglomeratic phase of this horizon is along the Big Darby Creek, about two miles above Georgesville. Here on the west bank the Messrs. Eckles have opened a small quarry to supply a neighborhood lime-kiln, and have thus laid bare a small section of rock with an excellent exposure of the conglomerate. The occurrence of such a conglomerate shows that the sediments of the Monroe formation had already been consolidated into a limestone and had been subjected to erosion before the deposition of the Columbus limestone took place. The meaning of this is probably that the sea in which the Monroe formation was deposited had withdrawn and the area in question was thus converted into dry land. Later the sea returned, from an easterly direction, and the pebbles, mixed with the basal sediments of the lower part of the Columbus limestone, were formed by wave action on the rocky formations of the coast. How much sediment was removed by erosion, or how many of the intervening formations of other localities were never deposited here, is uncertain; but a very considerable portion of the upper part of the Silurian and somewhat more than the entire lower Devonian, is now wanting. Hence the Columbus limestone is said to rest unconformably on the Monroe formation.

Columbus Limestone.¹—Succeeding the Monroe formation, as above stated, are about 105 feet of calcareous and magnesian deposits which have received the name, Columbus limestone (see Plate I). Of this formation, the lower 40 feet consist of a brown magnesian limestone containing much bituminous matter. It has a slightly banded structure, which is not nearly so pronounced as that of the formation just considered, and is more or less wavy. The beds or layers are massive, irregular, and rather indistinctly separated. Small masses of chert occur at more or less irregular intervals and occasionally pockets of calcite crystals are found. Although these layers usually show little sign of crystallization, sometimes blocks may be found which glisten with cleavage faces of calcite. Fossils are rare in this portion of the formation and those that have been found usually occur as moulds and

¹ For a more detailed account of the Middle Devonian formations, see Stauffer, C. R., *Geol. Surv. Ohio*, 4th Ser. Bull. No. 10, 1909.

casts which are poorly preserved. The barrenness of organic remains is probably not due to a poverty of its fauna during the time of the deposition of the original sediment, but to subsequent changes that have affected these layers. Chemically they approach a true dolomite¹ and like all other metamorphic processes, dolomitization frequently proves fatal to the preservation of fossils.

The upper 65 feet of the formation consist of highly calcareous crystalline gray limestone, which is very fossiliferous. Although the layers are usually even bedded, the bedding planes are sometimes uneven. This is due at times to stylolitic (hackle-tooth) structure and again to ripple-marks. It is the portion of the formation so extensively quarried at Marble Cliff and the familiar crushed rock used as a base in paving the city streets.

The Columbus limestone is doubtless the approximate equivalent of the Onondaga of New York, the Dundee of Michigan, the Corniferous of Ontario, and the Jeffersonville, including the Geneva, of Indiana and Kentucky. This is clearly demonstrated by the abundant fauna, many species of which are common to the various localities mentioned.

There are several features of special interest, exhibited by the upper portion of this formation, which deserve mention here. About nine feet below the top of the formation the "smooth rock" occurs.² This smooth plane or layer, as it is sometimes called, resembles a perfectly developed slickensides analogous to that frequently seen along a fault plane. Fossils occurring in it are planed off as smoothly as on a glaciated surface. Possibly it is a plane along which motion, between two portions of rock, has taken place—a shear plane—but the presence of wave-marks on some portions of the smooth surface renders this explanation doubtful. It has its most perfect development at Marble Cliff and State Quarries, but may be traced northward at least as far as Dublin. Sometimes, as at Casparis quarry, the shearing, if such it be, occurred along two parallel planes separated by an interval of about a foot; usually, however only one is to be seen.

The upper six or eight inches of the formation are frequently filled with the plates and teeth of fishes, and thus constitute the "bone-bed".³ "Here we have the assemblage of millions on millions of generally imperfect but mostly recognizable organs or fragments of the bony structure of the forms of fish life most characteristic of the Devonian age".⁴ These bones and teeth are in an excellent state of preservation, retaining even their original luster. The "bone-bed" is co-extensive with the outcrops of the central part of the state and is even well enough defined at Sandusky to be recognizable. An excellent place to see this layer is in the small run that enters the Scioto River from the east at

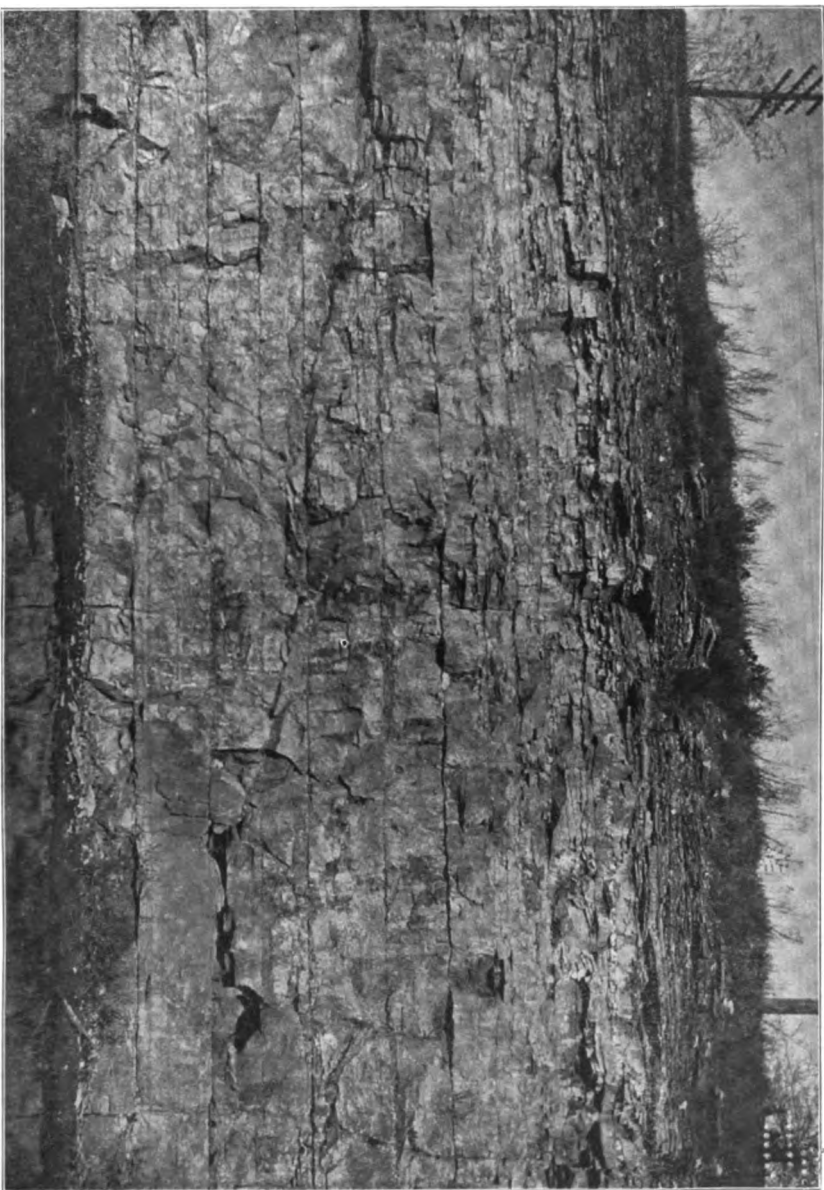
¹ Orton, Edward, Geol. Surv. Ohio, Vol. 3, 1878, pp. 615, 616.

² Orton, Edward, Geol. Surv. Ohio, Vol. 3, 1878, p. 610.

³ Orton, Edward, Geol. Surv. Ohio, Vol. 3, 1878, pp. 610, 611.

⁴ Newberry, J. S., Mono. U. S. Geol. Surv., Vol. 16, 1889, p. 30

PLATE I.



The Columbus limestone near Marble Cliff.

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Fishinger's bridge. The occurrence of such a persistent "bone-bed" in the upper few inches of the formation leads to the suggestion that perhaps this portion of the Devonian sea, teeming with its myriads of small organisms, was an exceptional feeding ground for those fishes whose remains contributed to its formation. Another possible reason for so remarkable an increase in the number of fish remains,¹ and especially at the top, may have been the wholesale destruction of these animals by some sudden change in the condition of the sea or by some agency of unknown cause. Notable modern instances of this are the destruction of the tile fishes along the Atlantic coast of North America in 1882 when it was estimated that a layer of fish several feet thick was formed over the entire sea-bottom of the region affected; or again along the Indian coast in 1897, when the Sumesar River was dammed by fish killed during the earthquake.²

Another feature to be mentioned is the chert beds. The occurrence of chert in limestones is a common phenomenon of many horizons and of almost every locality where they outcrop. In central Ohio it is more plentiful in the Delaware than in the Columbus limestone; however, in the latter there are several well defined zones. The more important of these is the zone located about 55 or 60 feet below the "bone-bed." This zone thins out to the north, but at the Storage Dam it measures about 9 feet. The chert is mainly in concretionary masses, the silica of which "was probably deposited in the form of the siliceous shells and spicules of plants and animals, and was disseminated through the sediments as originally formed." Subsequently it has been "aggregated into nodules of chert"³ and, by the process of replacement, changed calcareous to siliceous fossils.

Excellent outcrops of the Columbus limestone may be found along the Scioto River from Columbus northward beyond the limits of the area under discussion. The quarries at Marble Cliff (see Plate I) give a section which may be considered as typical of the upper part and a small portion of the lower may be seen just below the Columbus Storage Dam, while the entire thickness of this massive brown portion may be seen along the river near Bellepoint.

The following is a section measured near the north end of the Casparis quarry east of the Scioto River:

<i>Delaware limestone.</i>	Thickness.
12. Rather thin bedded bluish brown limestone containing some chert in the upper part, and all much weathered	5' 0"
11. Thin bedded bluish limestone, containing great quantities of black chert in definite layers	5' 10"

¹ Geikie, Archibald, Textbook of Geol., 4th Ed., 1903, p. 375.

² Oldham, R. D., Mem. Geol. Surv. of India. Report on the Indian Earthquake of June 12, 1897, p. 80.

³ Chamberlin, T. C., and Salisbury, R. D., Textbook of Geol., Vol. 1, 1905, p. 438.

Delaware limestone—Concluded.

Thickness.

10. Massive bluish limestone, with much black chert intermixed. The upper part is contorted, or more or less concretionary in appearance	3' 8"
9. Shale and some rather thick layers of bluish brown limestone, also containing a considerable quantity of black chert	5' 0"
8. Soft thin bedded grayish brown shale, with some chert	0' 6"

Columbus limestone.

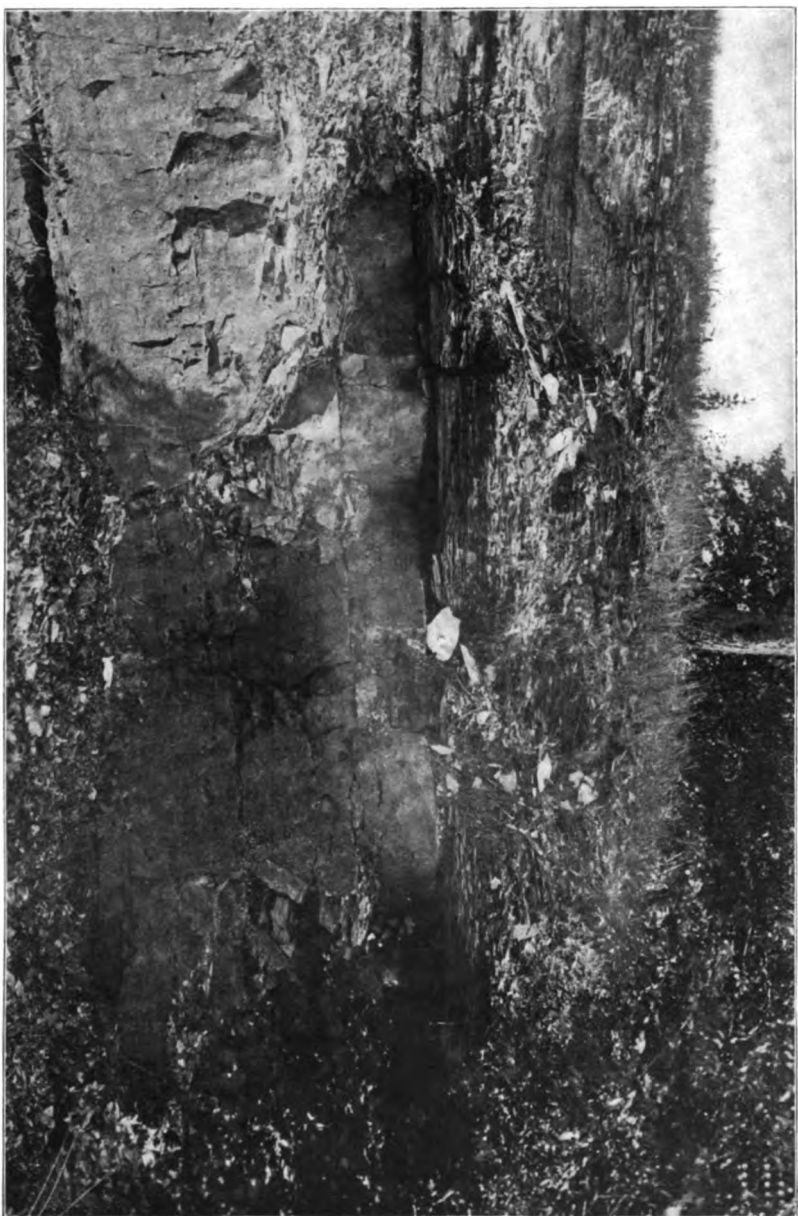
7. Well defined "bone-bed"	— —
6. Massive bluish gray sub-crystalline limestone, containing some gray white chert. <i>Spirifer acuminatus</i> and <i>Platyceras dumosum</i> are characteristic fossils	9' 4"
5. Smooth layer	— —
4. Very fossiliferous and fairly massive gray limestone. The weathered surfaces of this rock show numerous corals ..	8' 0"
3. Massive fossiliferous gray limestone. These layers show some prominent joints running approximately north and south. Characterized by the presence of such large cephalopods as <i>Gyroceras cyclops</i>	13' 0"
2. A layer of massive gray limestone exceedingly full of <i>Spirifer gregarius</i>	3' 6"
1. Massive fossiliferous gray limestone, extending to the bottom of the quarry	2' 6"

The quarries farther south are perhaps better for purposes of collecting fossils. The banks of the river, and especially the west bank, from Casparis south to the old State Quarries are simply shattered either by active quarries or abandoned pits. Among these the collector may find a wealth of fossils which is scarcely exceeded at any other locality.

Delaware Limestone.—The abrupt change from the pure organic sediments of the Columbus limestone to the argillaceous cherty blue limestones and calcareous brown shales of the Delaware is most strikingly illustrated in the sections of central Ohio. The five or six feet immediately succeeding the "bone-bed" consist of brown shale (see Plate II) in which Whitfield discovered a fauna which led him to correlate it with the horizon of the Marcellus shale of New York.¹ These fossils are mainly of species belonging to such genera as frequent the seas when black shale conditions prevail and may be found in nearly every outcrop of this horizon. The fauna of the Delaware limestone as a whole is intimately related to that of the Traverse group of Michigan and the Hamilton beds of New York, although it still retains, here in central Ohio, certain forms which are also of Onondaga age. These latter, however, are such as are usually common to the two formations mentioned, and hence it may be safely said that none of the characteristically Onondaga (Columbus) limestone fossils are known to have withstood the changed conditions of the Marcellus shale horizon. There is about thirty-six feet of the Delaware limestone in central Ohio, but it thickens notably to the north and also becomes a purer limestone. At Delaware, from which city the formation takes its name, it has been used quite extensively as a building stone.

¹ Whitfield, R. P., Proc. Am. Ass'n Adv. Sci., Vol. 28, 1880, p. 298; also Geol. Surv. Ohio, Vol. 7, 1893, pp. 432, 433.

PLATE II.



The shaly base of the Delaware overhanging the massive Columbus limestone.



Nearly every outcrop of rock along the Scioto River shows at least a small fraction of this formation. An excellent exposure may be seen along the Dublin pike on the east side of the river just beyond Fishinger's bridge, and the entire formation outcrops along Slate Run,¹ which passes through the grounds of the Columbus Fishing Club not far beyond. Another outcrop which is equally as interesting and shows the Olen tangy shale somewhat better is to be found along Bartholomew Run.² This run is located a mile north of the Franklin-Delaware county line and enters the Olen tangy River from the west, heading near Powell. The following section gives, in some detail, the rocks outcropping along this run.

<i>Ohio shale.</i>		Thickness.
25.	Black shale, rather thin bedded and considerably weathered. It contains a number of large spherical concretions....	16' 0"
<i>Olen tangy shale.</i>		
24.	Soft bluish marly shale, the upper part yellowish in color.	3' 10"
23.	Layer of flat, more or less disc-like, calcareous concretions.	0' 7"
22.	Soft blue marly shale, with some brown layers.....	7' 2"
21.	Layer of impure bluish limestone.....	0' 6"
20.	Bluish marly shale, with some thin bands of brown or black shale.....	2' 0"
19.	Black shale, containing some fragments of fossil plants....	0' 7"
18.	Marly blue shale.....	1' 0"
17.	Black shale cut into small blocks by two conspicuous systems of joints. Iron pyrites common.....	0' 3"
16.	Marly blue shale.....	1' 8"
15.	Two distinct layers of impure blue limestone.....	0' 4"
14.	Bluish green marly shale, containing thin bands of brown shale.....	2' 4"
13.	Brown shale with marl-filled marks, or trails of marine "worms." It also contains fragments of plants.....	0' 3"
12.	Soft bluish green marly shale, containing great numbers of small limestone concretions.....	5' 0"
11.	Brown shale with some "worm" trails through it, and containing a few bryozoans(?).....	0' 3"
10.	Bluish green shale, soft and gritless, showing some trails of marine animals.....	2' 4"
<i>Delaware limestone.</i>		
9.	Cherty blue to brown shaly limestone, the top of which is penetrated by the "worm" holes and filled with blue marl from above. Fish teeth and bones, somewhat water worn, and a few pebbles are also included in this shaly mass. At the present time this is the only known exposure of this contact.....	0 5"
8.	Very cherty bluish brown limestone. Layers rather even and sparingly fossiliferous. This is the zone which Winchell called "Tully limestone," and which Newberry conceded to contain a Hamilton fauna.....	9' 4"
7.	Granular layer of grayish brown limestone containing much iron pyrites which, in some cases, has replaced the original substance of the fossils. This thin zone contains a varied fauna notable among the species of which is the small globular coral, <i>Hadrophylum d'orbigny</i>	0' 8"
6.	Massive bluish limestone containing very little chert.....	2' 0"
5.	Thin bedded shaly limestone with much black chert.....	1' 0"

¹ Prosser, C. S., Jour. Geol., Vol. 13, 1905, pp. 426-430.

² Winchell, N. H., Geol. Surv. Ohio, Vol. 2, pt. 1, 1874, pp. 288, 289.

Delaware limestone—Concluded.

Thickness.

- | | |
|--|-------|
| 4. Blue to brown limestone containing iron pyrites and black chert intermingled and much contorted. These layers, together with the two just above, usually contain many specimens of <i>Grammysia bisulcata</i> | 4' 0" |
| 3. Rather massive blue limestone with some chert and shaly layers. <i>Tentaculites scalariformis</i> is a common fossil.... | 8' 0" |
| 2. Thin bedded brown calcareous shale with layers of black chert. It contains the Marcellus shale fauna..... | 7' 0" |
| 1. Brown limestone, somewhat shaly and probably a part of the above zone. These layers extend to the level of the run below the highway bridge..... | 2' 6" |

In the runs to the north of this there are many good sections of the Delaware limestone. Among these may be mentioned that in Deep Run¹



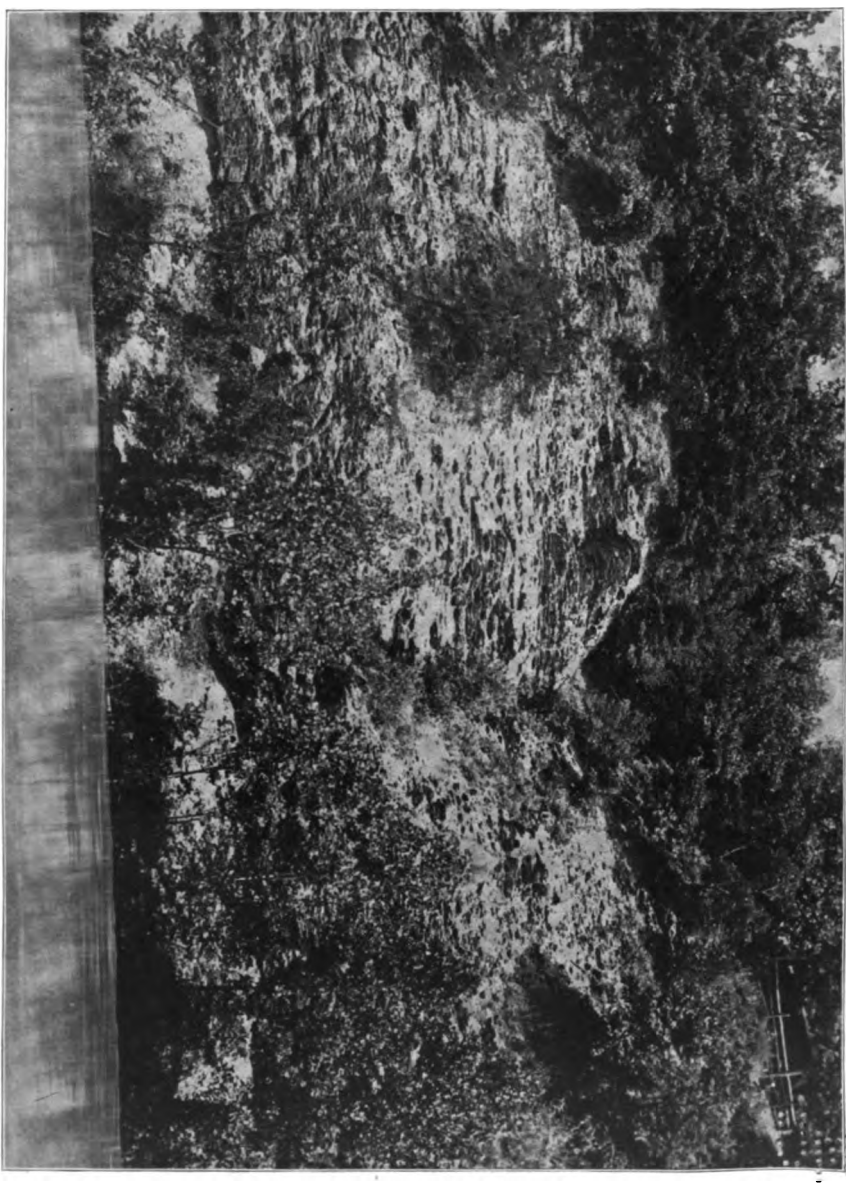
Fig. 2—The Olentangy shale, showing its basal portion and the uneven contact with the Delaware limestone below, as shown along Bartholomew Run in Delaware County. The observer stands on the summit of the Delaware limestone.

and the one on the Amelia Case farm, south of Liberty road. The Delaware limestone is not as fossiliferous as the Columbus limestone, but frequently layers may be found which have fossils in abundance. The fauna contains a much smaller number of species and is made up in part, as previously indicated, of species left over from Columbus time and in part of true Hamilton forms.

Olentangy Shale.—With the above formation may be classed the soft argillaceous blue deposit known as the Olentangy shale (see Plate

¹ Prosser, C. S., Jour. Geol., Vol. 13, 1905, pp. 430–433.

PLATE III.



"High Banks" along the Olentangy River north of Worthington. The illustration shows the clay-like constituency of the Olentangy shale and the firmer overhanging Ohio shale.

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III). They are successive stages in the general change from pure limestone to the strictly clastic deposits that follow. The Olentangy shale contains several thin layers of argillaceous limestone which are quite persistent in position. Towards the upper part of the formation occur layers of the black shale, similar to the Ohio, alternating with the soft blue layers, and also several more or less definite layers of flat calcareous concretions. Notwithstanding this, however, the contact with the Delaware limestone is sharp and the transition to the overlying Ohio shale is often sudden (see Figure 2). Sometimes the black shales are deposited on a surface which is decidedly uneven, with places where some sandy material has been found at the contact. Such contacts may be found at "Dripping Rock" on the Amelia Case farm and at the type section along the Olentangy River at Delaware.

The Olentangy shale is very poor in fossils. The only traces of animal remains found within this area are a few fish teeth, a crinoid stem, one pelecypod shell, which is probably a *Nucula*, and a bryozoan. Aside from these, however, there are several layers of a brown to purplish blue shale, occurring quite persistently in the lower part, which show markings thought to be "worm" trails. It is generally believed that this shale is of Hamilton age and this is probably true. Certainly its lithological appearance suggests such a disposition of the formation and so does its meager fauna in the outcrops just north of this region. That Newberry's Prout limestone¹ and marl is the northern equivalent of the Olentangy shale, is reasonably certain. The preceding section, measured along Bartholomew Run, gives a very good idea of the general make-up of the Olentangy shale (see Figure 2).

Ohio Shale.—The Ohio shale (see Plate IV) is the last formation of Devonian age in central Ohio. In fact it is probable that even the upper part of it may prove to be of Waverlyan age.² "The shale is brownish or bluish black in fresh exposures, but weathered surfaces have a distinctly blue color."³ This statement by Orton, while generally true, does not always hold for weathered surfaces. Frequently they retain their characteristic black color, except for the iron stains which may color the fragments a dull brown. While this shale is quite firm and somewhat massive at first, it soon falls into more or less thin laminae which finally break up into small fissile fragments and in the end weather into a rather stiff clay. It contains a considerable amount of iron pyrites, hence the dull brown of the weathered surface above referred to. The shale exhibits two quite regular systems of joints which, along Rocky Fork, are approximately northeast and northwest in direction.

A feature characteristic of this formation is the occurrence of large

¹ Newberry, J. S., Geol. Surv. Ohio, Vol. 2, pt. 1, 1874, pp. 189, 190

² See Ulrich, E. O., Bull. Geol. Soc. Am., vol. 22, 1911, correlation table II, opp. p. 608.

³ Orton, Edward, Geol. Surv. Ohio, Vol. 3, 1878, p. 634.

"iron-stone" concretions at several horizons (see Figure 3). They sometimes measure six feet or even more in diameter and are nearly perfect spheres, although there is some variety in form. Frequently the bedding planes may be traced into the concretion, showing that at least a part of the original shale matter is included within the mass. These concretions, in common with most others, are thought to be secondary products formed *in situ* by the aggregation¹ of like matter, usually about



Fig. 3—Concretions weathered out of the Ohio shale. Bartholomew Run.

some fragment of foreign material as a nucleus. This may be suspected from the fact that the shale layers are heaved up over and depressed below the concretions, and from the uniformity of composition of the individuals especially in concentric layers. The nuclei of these concretions are frequently found to be crystalline masses; such minerals as calcite, barite and selenite having been found. In other cases organic matter, such as a fish bone or a piece of wood,² has served as a center about which the accumulation occurred. These concretions are usually more frequent in the lower forty or fifty feet of the formation.

In the upper part of the formation calcereous bands from a fraction to several inches in thickness frequently occur. These exhibit the peculiar "cone-in-cone" structure common in several of the Ohio formations.³ The cones are in two series, one with the bases upward and the other with the bases downward. The origin of this structure is un-

¹ See Chamberlin and Salisbury's Textbook of Geol., Vol. 1, 1905, pp. 438, 490-493.

² Orton, Edward, Geol. Surv. Ohio, Vol. 3, 1878, p. 635.

³ Newberry, J. S., Geol. Surv. Ohio, Vol. 1, pt. 1, 1873, p. 211.

PLATE IV.



The Ohio shale, with concretions in place, at "The Narrows," about 1½ miles north of Worthington.



known. It has been referred to concretionary action, but probably it is in some way connected with the compressive stresses developed by the load of overlying sediments. Near the upper limit of the formation is a layer of numerous small flat concretions of iron pyrites. This layer is rather persistent in the vicinity of Central College and to the south.

Aside from the impressions of long flat leaves of certain plants, spore cases, a few *Calamites*, the fossil wood associated with some concretions, and occasional fish bones, the great body of this formation is practically barren of fossils in this region. In the extreme upper portion, however, fossils like those of the Cleveland shale are sometimes found. Some of these are very similar to the forms occurring in the Bedford shale.

The Ohio shale becomes the St. Clair shale¹ of Michigan and the New Albany black shale of Indiana² and Kentucky. These deposits are supposed to be of Genesee age. In all probability they represent the sediment accumulated in this section of the sea while the Genesee, Portage and Chemung, in part, were being deposited in New York.³

There are numerous excellent sections of the Devonian shales to be found in the deep valleys of the tributaries to the Olentangy River, from Stratford to Worthington and even at North Columbus. Notable among these are the outcrops at High Banks, Glen Mary, the Narrows, etc. The shales of all these sections are, however, practically identical.

The following section, which was measured in the Narrows, shows the variable composition of this black shale as it occurs in central Ohio:

Ohio shale.		Thickness.
17.	Drift	4' 0"
16.	Black shales	38' 8"
15.	Bluish gray shales alternating with black, and all apparently more fissile than that below	6' 0"
14.	Layer of cone-in-cone	0' 1"
13.	Bluish gray shales alternating with black shale	15' 4"
12.	Bluish gray shales with several layers of cone-in-cone	0' 6"
11.	Black shales with some bluish gray layers	6' 8"
10.	Black shales with few or no concretions	16' 0"
9.	Black shale containing a great many spherical concretions ..	21' 4"
8.	Black shales showing streaks of bluish gray running through the beds. Also some bluish gray shales alternating with the black, and this is especially true in the upper part ..	10' 8"
7.	Black shales alternating with bluish gray shales	6' 4"
6.	Black shales showing prominent oblique joints. Direction of jointing, northeast and southwest	9' 8"
5.	Band of bluish gray shales	0' 8"
4.	Black shale	0' 6"
3.	Band of bluish gray shales	0' 10"
2.	Black shale with very prominent joints running northeast and southwest. This shale contains numerous small iron pyrites concretions and some of the usual large spherical concretions	8' 8"
1.	Covered interval to the level of the Olentangy River	6' 8"

¹ Geol. Surv. Mich., Vol. 3, 1876, pp. 64-68; also idem, Vol. 5, pt. II, 1895, p. 21, 22; and idem, Vol. 7, pt. I, 1900, pp. 25-30.

² 5th Ann. Rept. Geol. Surv. Ind., (1873), 1874, p. 158; also idem, 25th Ann. Rept., (1900), 1901, pp. 340, 341, 532, 533.

³ Newberry, J. S., Geol. Surv. Ohio, Vol. 1, pt. 1, 1873, pp. 69-71.

Along Alum Creek, which crosses the northeast quarter of the quadrangle from north to south and joins the Big Walnut a short distance southeast of Columbus, excellent outcrops of the Ohio shale occur; in fact the valley of this stream lies wholly within this formation. About the best of these outcrops is that along the run at Cheshire, at the extreme north end of the quadrangle, where some forty feet of the black shale may be seen. Another very good section may be found just east of Blendon, along a run entering Alum Creek from the east.

The key to the stratigraphy of the east half of the quadrangle is to be found along Big Walnut Creek, although in the southeast quarter interest is somewhat divided among Big Walnut, Black Lick and Little Walnut Creeks. The former of these streams flows almost along the line of outcrop of the lower Waverlyan formations; in fact, south of Galena, the Bedford shale was found west of this stream only at Central College. Many places where the east bluff has a fine outcrop of shale, the west, at no great distance, will show nearly all till (glacial clay and boulders). This is partly due to the presence of a buried pre-glacial valley, along the eastern wall of which the modern Big Walnut Creek flows from Galena southward.

Bedford Shale.—With the Bedford shale begins the Mississippian system and the Waverlyan series of classic geological literature. The Waverlyan is recognized in Michigan,¹ where it has been called the Marshall series.² It is also known to be closely related to the Knobstone of Indiana,³ and the Kinderhook of farther west. The Bedford shale is usually an argillaceous deposit (see Plate V) varying in color from bluish gray to red or chocolate brown, the red color usually being confined to the middle portion. Where the outcrop is fresh, as in the bed of a stream, the layers appear massive, but on exposure they soon weather into a sticky red or yellow clay. A fine example of this formation in weathered condition may be seen in the hills east of Central College. Here the Bedford shale forms a line of bluffs along the east bank of Big Walnut Creek where the soft and easily eroded shale has assumed a most striking topography resembling, to a limited extent, that of the "Bad Lands" of the West. The color of the central portion of the formation is so conspicuous here as to have fastened the name "Red Hills" upon this locality.

In the lower part of this formation, especially in the northeast quarter of the area, are several layers of small flat argillaceous concretions which show a decidedly concentric structure. Layer after layer may be broken off by the blow of a hammer. An occasional fossil has been found in these concretions. In the southeast quarter of the quadrangle, near Lithopolis, very much larger concretions of an irregular

¹ Geol. Surv. Mich., Vol. 3, 1876, pp. 69-101.

² Idem, Rept. Prog., 1861, pp. 80-88.

³ 25th Ann. Rept. Geol. Surv. Ind., 1900, pp. 339, 340.

PLATE V.



The lower part of the illustration shows the contorted condition of the Bedford shale; and the upper, the basal layers of the Beres *grit* along Rocky Fork, east of Gahanna.

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shape are often found. One of the most notable characteristics of the formation in this part of the state, and the same is true in the vicinity of Cleveland, is the disturbed condition of the sediments forming the upper portion. These layers are frequently much contorted and sometimes even crushed while the overlying Berea is little or not at all affected. The nature of the material of which the Bedford shale is formed indicates that it was probably deposited some distance from shore. Perhaps at the outer margin of these mud deposits, or even elsewhere, steep sub-marine slopes occurred. The slumping or superficial faulting¹ of such deposits would result in the contortion of the layers, especially if the material was sufficiently tenacious to hold together.

Dr. Prosser considers the prominent concretionary layer occurring along Rocky Fork as forming the base of the Berea grit². This is possibly the proper boundary line for that locality, but it must not be expected that such a layer usually or even often marks the contact. Indeed it is frequently impossible to say where the shale ends and the sandstone begins. The upper part of the Bedford is usually arenaceous. Gradually thin layers of sandstone begin to appear and these keep increasing in number until the shale is in the minority and finally disappears. Moreover these thin sandstone layers are well ripple-marked, showing the same shore conditions that existed during the deposition of at least a large part of the Berea. Such is the condition of these sediments along Big Walnut Creek between Galena and Sunbury. However along Rattlesnake Creek, near its junction with Big Walnut Creek, there is a massive concretionary layer which, from the fact that it marks the real beginning of the sandstone, may possibly be taken as Berea grit and hence probably the beginning of that formation. However the usual sediments of the Berea are rather coarser and more massively bedded than those of the sandy layers in the Bedford. Hence there is a disposition on the part of some geologists to throw all these questionable central Ohio beds into the Bedford, leaving only the massive coarse sandstones at the top in the Berea.

The Bedford shale is also one of the essentially non-fossiliferous formations. From one to two feet of the basal layers, however, are frequently very full of fossils. This fauna is no less remarkable in its association of species than is its occurrence here among these almost barren deposits. While it contains a Devonian element linking it, in a general way, to the Hamilton,³ yet its affinities are more nearly with the Kinderhook, which itself contains a Hamilton element. The Rockford limestone of Indiana and the Glen Park limestone⁴ of Illinois carry related faunas, a fact which points to a possible solution of the problem.

¹ Chamberlin, T. C., and Salisbury, R. D., *Textbook of Geol.*, Vol. 1, 1905, p. 527.

² Prosser, C. S., *Jour. Geol.*, Vol. 10, 1902, pp. 276, 278; also *Am. Geol. Vol. 34*, 1904, p. 340, foot note.

³ Herrick, C. L., *Rept. Geol. Surv. Ohio*, Vol. 7, 1894, p. 507.

⁴ Weller, Stuart, *Trans. Acad. Scil., St. Louis*, Vol. 16, No. 7, pp. 467, 470.

Over Ohio and eastward the Hamilton fauna disappeared during the deposition of the Black shales, while in the west it continued to flourish and undergo changes due in part to the usual processes of evolution and again to the addition of some new species. A decided deepening of this Ohio portion of the sea probably occurred at the beginning of the Mississippian and with it the faunas of the purer western sea migrated across Indiana and Kentucky into Ohio. Hence the Bedford fauna is decidedly western in its affinities with here and there an eastern species, while the entire fauna still bears a marked resemblance to its ancestral association of species.

The outcrops which furnish good sections of the Bedford shale are so numerous that there is little necessity in calling attention to them. The sections here given are selected because they are fairly accessible and also show some of the succeeding formations excellently.

The following is a combined section of the outcrops occurring along Rocky Fork from its union with Big Walnut Creek below Gahanna to the upper part of the tributary which flows through New Albany.

<i>Cuyahoga formation.</i>		Thickness.
18.	Thin bedded sandstones and some bluish colored shales. This portion of the section is exposed along the tributary flowing through New Albany.....	50' 0"
17.	Soft bluish shale	5' 0"
<i>Sunbury shale.</i>		
16.	Covered interval, most of it probably belonging to the Sunbury shale	10' 0"
15.	Fissile black shale, iron stained, and somewhat decomposed. The lower two or three inches contain quite an abundance of two or three species of Brachiopods. This portion is best exposed along a small tributary at the bend of Rocky Fork just south of the highway, where the Ealy mill formerly stood	25' 8"
<i>Berea grit.</i>		
14.	Rather massive sandstone layers, many in lenticular beds, and some showing ripple-marks. A layer of marcasite occurs on top	17' 6"
13.	Layers of fine grained sandstones from a fraction to ten inches in thickness, and well ripple-marked. Some layers are much contorted, in places, and contain local beds of shale	8' 6"
12.	Arenaceous gray shale, which grades into the sandstone up stream. It contains some thin layers of ripple-marked sandstones	12' 0"
11.	Concretionary layer, which is thought to form the limiting layer of the Berea	1' 0"
<i>Bedford shales.</i>		
10.	Soft argillaceous blue shales, becoming arenaceous towards the top. Some of the slab-like fragments when freshly exposed show marks resembling the impressions of plant stems	38' 8"
9.	Soft argillaceous gray mottled shales	8' 0"
8.	Soft fissile red to chocolate brown shale. These layers weather rapidly into a stiff clay	25' 6"
7.	Soft argillaceous blue shale, quite fissile and much jointed.	15' 6"
6.	Argillaceous blue shale, very fossiliferous and especially so near the base	2' 0"
5.	Dark bluish brown rather soft shale, containing some fossil shells and worm trails (?), the latter cast in iron pyrites.	0' 4"

<i>Ohio shale.</i>	Thickness.
4. Black shale prominently jointed (joints N. E. and N. W.), and much iron stained.....	5' 0"
3. Covered interval (aneroid reading)	5' 0"
2. Black shale	10' 8"
1. Black shale with several layers of "cone-in-cone" to level of Big Walnut Creek	8' 10"

The Bedford shale is well exposed at Taylor's station on the Pennsylvania and the Baltimore and Ohio Railroads, where it is being used in the manufacture of brick and tile. The contact with the Ohio shale may also be found at that place.

Along Duncan Run, which enters Big Walnut Creek a mile and a quarter north of the Franklin-Delaware county line, there is an exceptionally fine section through the greater portion of the Waverlyan series and into the Devonian. The following section gives the gross measurements taken in the cut made by this run.

<i>Cuyahoga formation.</i>	Thickness.
11. Blue to gray sandstones in layers from a few inches to six or eight in thickness	5' 0"
10. Bluish gray shale, alternating with shaly sandstones, the surface of which show some marks resembling impressions of plant stems or trails of animals	10' 0"
9. Gray shale, not well exposed	5' 0"

<i>Sunbury shale.</i>	
8. A fissile black shale. The contact with the Berea grit is shown back of Harlem, but the contact with the Cuyahoga formation is slightly covered	30' 0"

<i>Berea grit.</i>	
7. Buff to bluish gray fine grained sandstones, the upper layer much iron stained. The lower layers are rather thin shaly and well ripple-marked. At Harlem this stone has been quarried and crushed for road material; for which purpose, when mixed or covered with crushed limestone, it is said to serve excellently. In the quarry here it is a fine-grained bluish sandstone, rather compact and often banded.....	40' 0"

<i>Bedford shale.</i>	
6. Mottled and gray argillaceous shales, with some sandy layers	28' 6"
5. Soft red or chocolate brown shales	16' 0"
4. Gray shales with a few thin layers of chocolate brown shale. 12' ..	4"
3. Layer of very compact hard red or chocolate brown shale. 0' ..	4"
2. Soft gray argillaceous shale containing fossils in the lower part.....	2' 10"

<i>Ohio shale.</i>	
1. Firm black shale to level of Big Walnut Creek	55' 0"

From this section it will be observed that the Bedford shale decreases in thickness to the northward. By the time the Sunbury region is reached an even greater decrease is noticed, while the simultaneous thickening of the Berea grit is a feature of the northward sections. This variation is somewhat relieved, however, if the lower thin bedded sandstones are considered as a part of the Bedford shale.

Berea Grit¹.—The Berea 'grit is the earliest persistent sandstone formation occurring in central Ohio. It is a rather fine grained gray to buff colored rock laid down in beds of varying thickness which usually become more massive towards the top of the formation. The beds frequently show a tendency to feather out or to increase in thickness as traced along a cliff. Distortion or concretionary effects (see Figure 4) are common throughout a large part of the formation as defined in central Ohio. This condition may frequently be seen to pass into the ordinary layers of the formation. The thin layers, and many of the thicker as well, are excellently ripple-marked. These ripple-marked

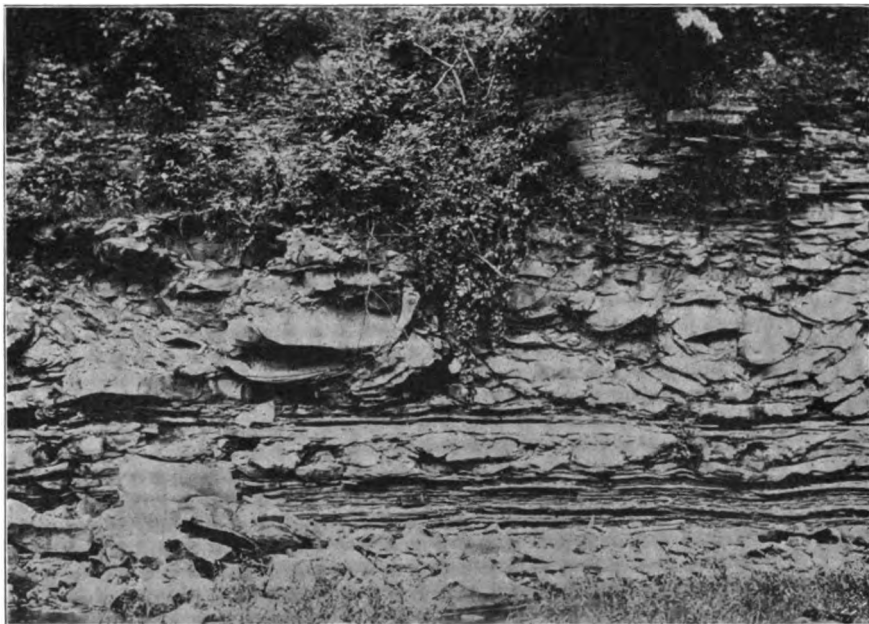


Fig. 4—The peculiar concretionary structure common in the Berea grit, at Sunbury.

layers are sometimes contorted into various shapes, showing that whatever produced the twisting of these beds was operative since the deposition of the sediment and not contemporaneous with it. A notable feature of this formation, and one worthy of mention since it is so persistent, is the occurrence of a layer of marcasite on the extreme upper surface. The decomposition of this sulphide of iron gives rise to the hydrogen sulphide of the sulphur springs to be found along Rocky Fork.

Fossils are rare in this formation, in fact none were found in the outcrops of this entire region. As already mentioned, the Berea grit is quite variable in thickness. In the southeastern part of the area it lies unconformably on the Bedford shale and is reduced to about four feet, while at Sunbury it is probably more than sixty-five feet in thick-

¹ Berea sandstone is often used instead of Berea grit.

ness. The Berea grit takes its name from the village of Berea, Cuyahoga County, where the formation is extensively used in the manufacture of grindstones, for building stone, curbing, flagstone, etc. In southeastern Ohio this formation becomes one of the important oil and gas horizons.

The Berea grit is well shown in the sections just given. The following section, which was measured along Rattlesnake Creek opposite the village of Sunbury, shows a greater thickness of this rock:

<i>Cuyahoga formation.</i>		Thickness	
12.	Soft blue shale, composing the base of the formation	5'	0"
<i>Sunbury shale.</i>			
11.	Meager outcrops of bituminous black shale, somewhat iron stained	12'	0"
10.	Partly covered interval of black shale	5'	0"
<i>Berea grit.</i>			
9.	Rather thin bedded gray to buff sandstone. The upper four-inch layer contains a great deal of sulphide of iron (Aneroid reading)	25'	0"
8.	Fairly thick layers of sandstone showing a lenticular shape and interbedded with thin layers	15'	0"
7.	Concretionary masses of sandstone with thin shaly layers, all more or less disturbed	5'	0"
6.	Ripple-marked thin shaly sandstone layers, somewhat banded	5'	0"
5.	Rather massive layers of sandstone interbedded with some shale. The massive layers are more or less concretionary	5'	0"
4.	Soft arenaceous shale containing some concretions	6'	8"
3.	Layer of massive concretions more or less continuous, but sometimes interrupted and apparently somewhat replaced by the bluish shale	3'	0"
<i>Bedford shale.</i>			
2.	Bluish gray shale, which is rather argillaceous, but somewhat gritty	2'	0"
1.	Covered to level of Big Walnut Creek	5'	0"

The Berea grit has been quarried to some extent along the banks of this creek, however it is worth but little for commercial purposes.

Sunbury Shale.—The disappearance of the sandy sediments is no less remarkable than it is sudden. Few horizons are more marked than is the contact between the Berea grit and the Sunbury shale. So sharp is this line that we may be absolutely certain, within a fraction of an inch, where one leaves off and the other begins. The Sunbury is a black argillaceous shale with much bituminous matter resembling somewhat, in general appearance, the Ohio shale. However, it is thinner bedded, more fissile and resists weathering less than does the Ohio. The lower layers of this shale cling with wonderful tenacity to the top of the Berea grit. So often is this the case that large areas exist with but a few inches of black shale separating the sandstone from the glacial drift above. The lower six or eight inches of the Sunbury shale are often quite fossiliferous, although the number of species is small. The most numerous of these fossils are *Lingula melie* and *Orbiculoidea newberryi*, which will be recognized as such genera as are usually associated

with black shale conditions. The great body of the deposit, however, is essentially non-fossiliferous.

Prof. Hicks' typical locality for the Sunbury shale is along Rattlesnake Creek¹ east of Sunbury. Much better outcrops, however, occur along Rocky Fork northeast of Gahanna and especially in Dutch Hollow at Lithopolis. Some of these sections have already been given while that of this latter place will be given in connection with the following formation.

Cuyahoga Formation.—In all sections where the contact between the Sunbury shale and the Cuyahoga formation is exposed, the latter begins with about five feet of bluish gray argillaceous shale. This is followed by fine grained sandstones alternating with shales and all usually bluish in color. In the southern part of the State several of the persistent sandstone layers have received definite names, viz.: Buena Vista stone² and City Ledge.³ Dr. Prosser has revived these names and applied them to their equivalents⁴ in central Ohio. He calls the lower fifty feet of the Cuyahoga formation the Buena Vista stone and states that the lowest sandstone of the formation apparently corresponds to the stratum termed the "City Ledge" in southern Ohio. No fossils, other than fragments of plants, and vermicular markings were found in these shales and sandstones, although at some localities in the northern and southern parts of the state very considerable collections of animal remains have been made from it.

The following section was measured along the little run in Dutch Hollow (see Plate VI) at Lithopolis.⁵ It begins near the eight-hundred-foot contour line, three-quarters of a mile northwest of the covered bridge, and runs up stream for a distance of a mile.

<i>Cuyahoga formation.</i>	Thickness.
10. Several fairly even compact layers of grayish sandstone, followed in ascending order by bands of arenaceous gray shale and soft uneven sandstone layers to the crest of the hill at the Lyndecker quarry. The shales contain fragments of plants, but no other fossils were found in these layers	31' 0"
9. Compact even grained blue freestone. This is the only layer of sandstone extensively worked in the quarry, where it is said to extend for hundreds of feet without a cross joint	4' 0"
8. Layers of sandstone interbedded with shales and thin shaly sandstones outcropping above the covered bridge and along the steep bank below	31' 0"
7. Massive layer of blue, but frequently iron-stained sandstone.	2' 0"
6. Arenaceous gray shales and thin layers of blue sandstone.	4' 2"
5. A massive layer of iron-stained blue sandstone, the "City Ledge"	2' 9"
4. Very soft gray shale composing the base of the formation, wherever this part has been found outcropping	5' 0"

¹ Am. Jour. Sci., 3rd Ser., Vol. 16, 1878, p. 216.

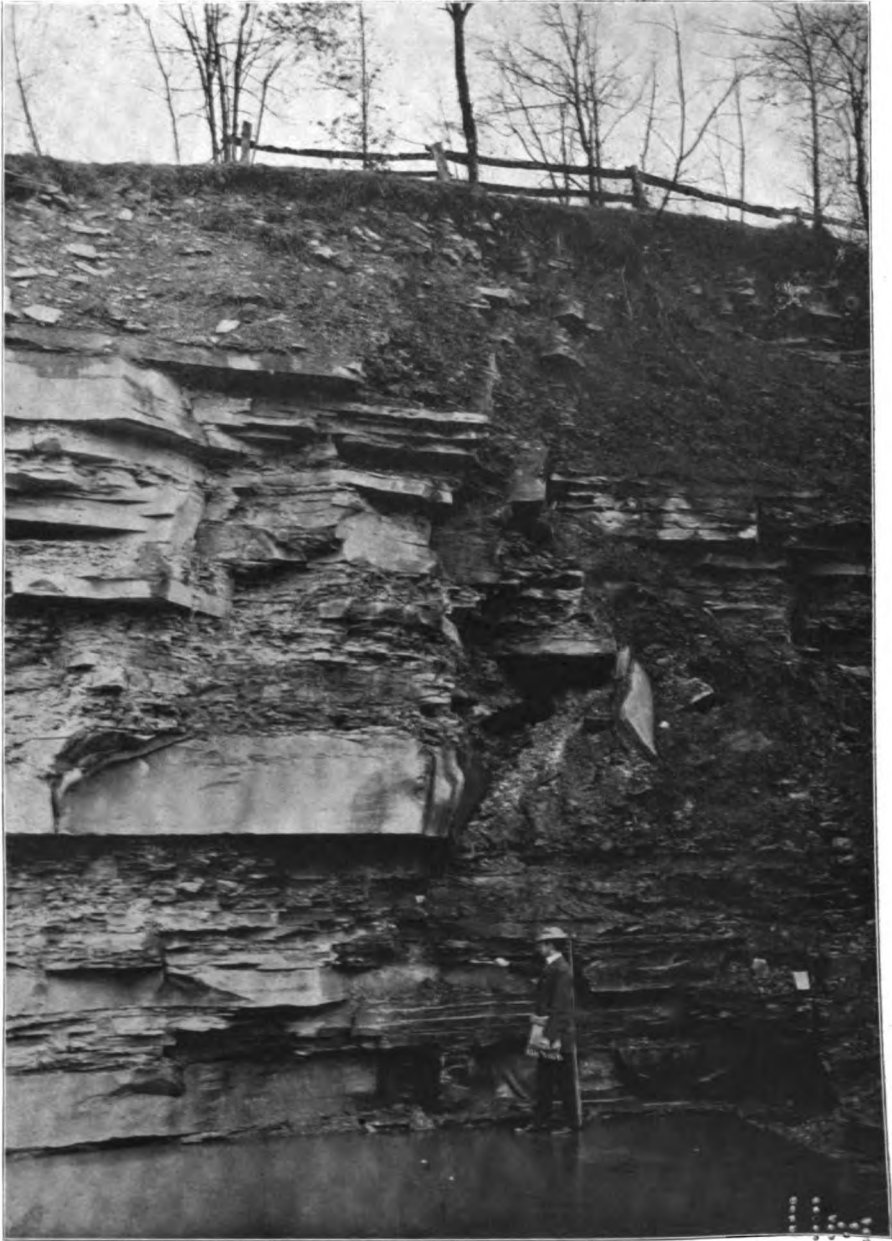
² Orton, Edward, Geol. Surv. Ohio, Vol. 2, pt. 1, 1874, p. 626.

³ Idem, 2nd Ann. Rept., 1838, pp. 263, 264.

⁴ Am. Geol., Vol. 34, 1904, pp. 337, 341, foot note.

⁵ For a more detailed account of this section and also of other sections in this vicinity, see Prosser, C. S., on "The Waverly Formations of Central Ohio." Am. Geol., Vol. 34, 1904, pp. 335-361.

PLATE VI.



View of the lower portion of the Cyahoga formation at Lithopolis.



Sunbury shale.

Thickness.

3. Fissile black shale in very thin laminae and considerably iron stained in old exposures. Near the outcrop of the Berea grit this shale rises fifteen feet in the south bank of the run. In the north bank, a little farther up stream, is another fifteen-foot bank capped by the bluish gray shales of No. 4. The characteristic fossils of the base of the Sunbury shale—*Lingula melie* and *Orbiculoides newberryi*—were found at this place 26' 0"

Berea grit.

2. Fairly coarse grained gray sandstone occurring in the bed of the run and in the bank at the lower end of the outcrop. Layers thick, compact and with no intercalated shale. The upper part of the exposure is in contact with the black shale of the next succeeding division of the section, and is strongly impregnated with iron pyrites, which occurs in small nodules or concretions. Ripple-marked 5' 0"

Bedford shale.

1. Soft argillaceous shale, drab in color, but stained yellow where weathered 8' 0"

The shales of the Cuyahoga formation frequently contain flat iron-stone concretions and occasionally other concretions in which fossils have been found.

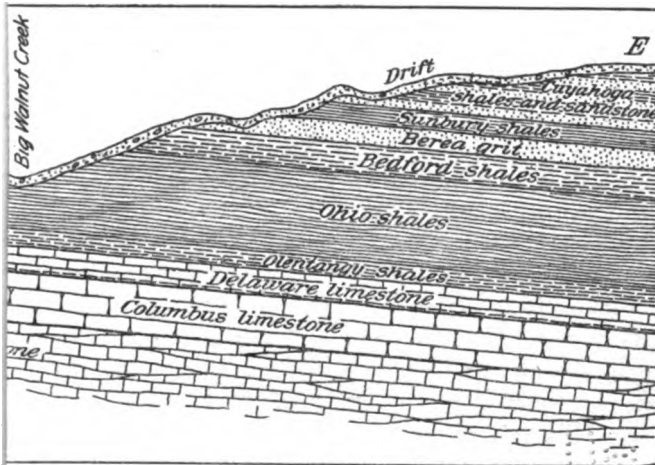
Black Hand Formation.—Only a very small portion of the area here discussed is covered by the Black Hand formation. This is the hilly region about two miles east of Lithopolis and known as Chestnut Ridge. The formation consists of soft, coarse grained sandstones which vary in color from yellow or buff to brown and red. It is frequently cross-bedded and often very massive. Occasionally the rock contains a number of quartz pebbles. Portions of the formation contain some fossils, but none were found in the region under consideration.

Chestnut Ridge forms the most conspicuous feature of the landscape in a region of uniformly low relief. Its topography at once suggests interesting geological features and the expectation is by no means disappointed, for this ridge proves to be composed of the very coarse massive yellow sandstone which constitutes the base of the formation so extensively developed in the Hocking Valley, ten miles to the east. These hills are therefore geologically and topographically the outliers of the picturesquely eroded region that gives to the Hocking Valley its beautiful scenery, and owe their existence to the greater resistance to weathering and erosion, of the formation which caps them.

The region about Jefferson affords a clue to the geology of the ridge. One and one-half miles northwest of this village, twenty feet of red Bedford shale overlain by Berea grit is exposed in the south bank of Little Walnut Creek at the covered bridge. The Sunbury shale and the lower part of the Cuyahoga formation are not exposed nearer than Lithopolis. At the north end of Chestnut Ridge, at the southern edge

litia alta, a small bivalve Crustacean, is sometimes rather plentiful. *er vanuxemi* has occasionally been found. This *Spirifer* shows the

PLATE VII.



¹ See Grabau, A. W., and Sherzer, W. H., Mich. Geol. and Biol. Surv. Pub. 2, Geol. Ser. 1, 1910.

they are rather distinctive. *Paracyclas elliptica* and *Conocardium cuneus* are the more common. Gastropods are quite abundant, especially in the cherty layers above the coral zone. These often have the external markings well preserved. *Platyceras dumosum* is almost always to be found a few feet below the "bone-bed." Cephalopods occur more or less frequently throughout the formation. The large coiled form, *Ryticeras cyclops*, is sometimes fairly common in the middle portion of the formation.

The pygidia or tails of trilobites are to be found occasionally and the heads more rarely. These belong to a half dozen or so genera, of which the more common are figured on the plates herewith. Fish remains are usually limited to the teeth, spines and fragments of the dermal plates. But occasionally the jaws with the teeth in place are found and even at times the whole cranial covering may occur as a fossil. These latter are so conspicuous that they are noticed and collected even by workmen in the quarries.

Delaware Limestone.—(Plate XII.) The fossils of the Delaware limestone differ from those of the preceding chiefly in the fewer number of species and in the less abundance of those that do occur. There is, however, the introduction of certain species which occur in more recent rocks in New York State. These come in with the beginning of the formation when such a characteristic Marcellus species as *Leiorhynchus limitare* is introduced into the basal shaly layers. Some of the other conspicuous forms which do not occur below the "bone-bed" are *Delthyris consobrina*, *Chonetes deflectus*, *Martinia maia*, *Grammysia bisulcata*, etc.

Olentangy Shale.—The Olentangy shale has yielded but few fossils near Columbus. One or two fragmentary fossil shells and some fish teeth in the basal portion constitute nearly the whole fauna. At Delaware, however, a small but thrifty crinoid bed was found.

Ohio Shale.—The fossils of the Ohio shale are rare and often inconspicuous. Those usually found are leaves or fragments of plants and their spore cases. A few fish bones and conodont teeth have also been found in the formation.

Waverlyan Series.—(Plate XIII) Within the area here under consideration the only horizons found to be fossiliferous are the base of the Bedford shale and the base of the Sunbury shale. The most conspicuous fossils of the latter horizon are *Orbiculoidea newberryi* and *Lingula melie*. In the former, or base of the Bedford shale, the fauna is quite large and varied; unfortunately, however, it is still but little known as some of the species have possibly never been described. The relationships and sudden appearance of this fauna have been discussed in the preceding pages. *Palaeoneilo bedfordensis* is one of the common

fossils. Every Waverlyan formation has yielded fossils at some point within the state. The Cuyahoga perhaps contains the larger fauna and especially is this true in the northern part of the state. The plate of Waverlyan fossils here given illustrates species collected in that section and mostly from the Cuyahoga formation. It is intended mainly to represent the Waverlyan fauna in contrast to that of the preceding formations. The introduction of *Productus* and *Syringothyris* is significant of the Mississippian age.

Syringothyris appears in the Senonian

EXPLANATIONS OF PLATES.¹

PLATE VIII.

MONROE LIMESTONE FOSSILS.

Brachiopods.

- Spindella? (Greenfieldia) whitfieldi Grabau*
 Fig. 1. *Meristella bella* Hall. *Ohioensis Grabau (var.)*
 Figs. 2,3. *Spirifer vanuxemi* Hall. Note the simple plications and the un-plicated fold and sinus. These are characteristics of early Spirifers.

Crustaceans.

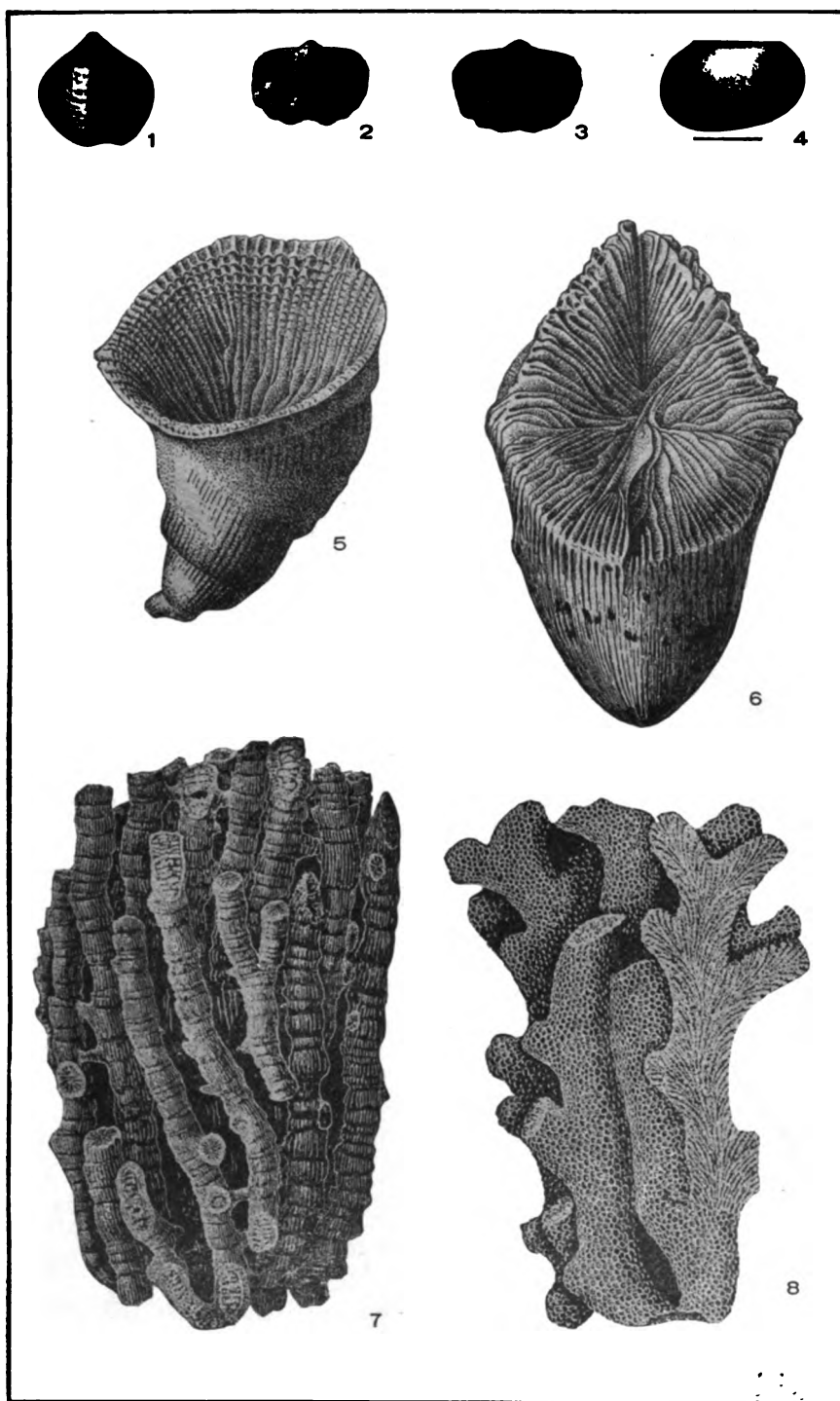
- Leperditia alta Grabau*
 Fig. 4. *Leperditia alta* Conrad. This is the more common fossil. It often looks like a small pebble in the rock.

COLUMBUS LIMESTONE FOSSILS.

Corals.

- Fig. 5. *Heliophyllum corniculum* (Lesueur). This is one of the simple Corals. It is sometimes called a cup or horn Coral, because of its shape. It occurs throughout the formation, but is probably more abundant in the upper part.
 Fig. 6. *Aulacophyllum sulcatum* (d'Orbigny). This is another of the simple Corals. Compare the septae (divisions on the inside) with those of the preceding.
 Fig. 7. *Synaptophyllum simcoense* (Billings). One of the common compound Corals. It is made up of a number of individuals growing in a colony.
 Fig. 8. *Favosites limitaris* Rominger. Another of the compound Corals.

¹ The illustrations of fossils used in this bulletin are chiefly after Hall, and from earlier reports by the Ohio survey.



Monroe and Columbus limestone fossils.

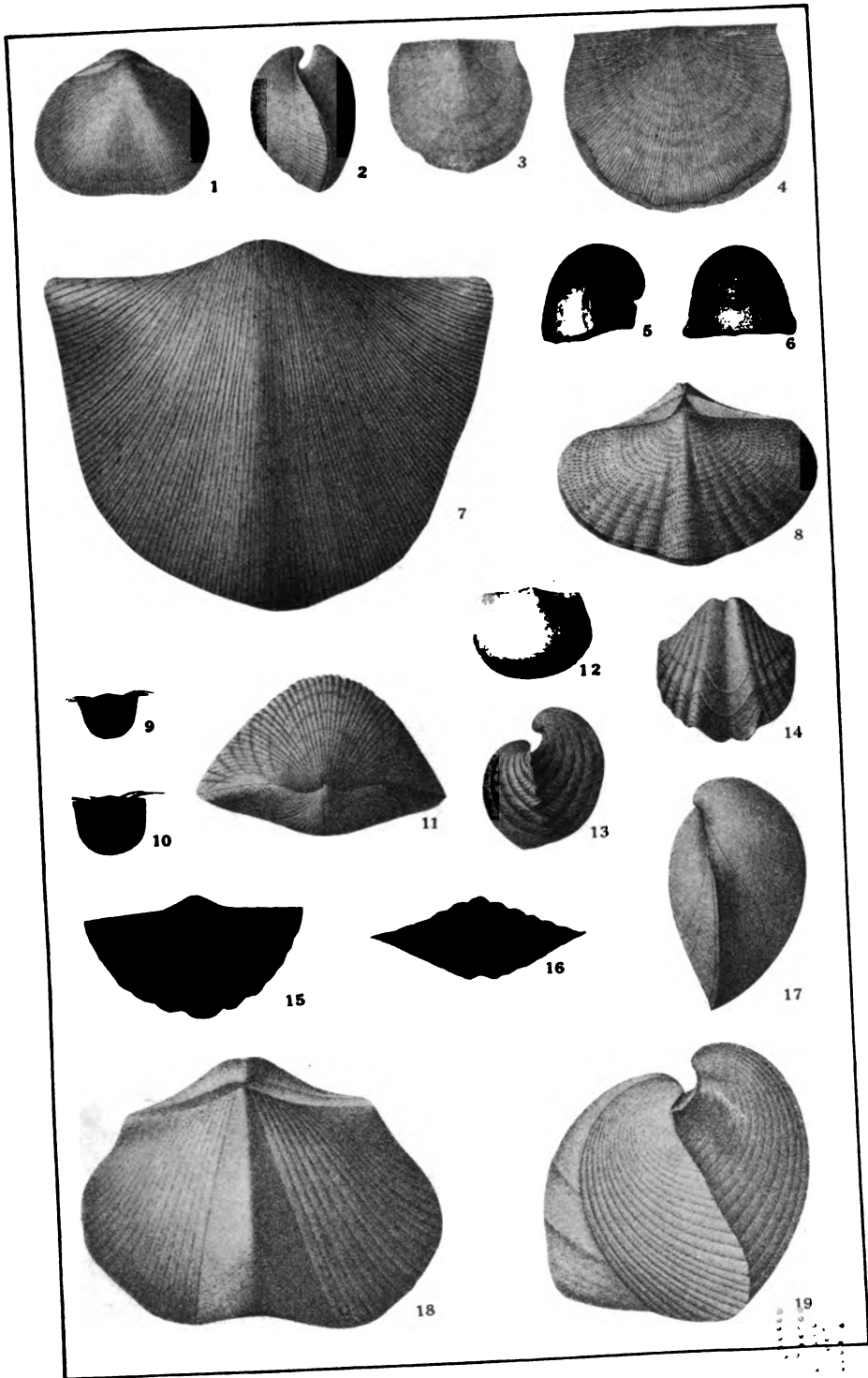
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PLATE IX.

COLUMBUS LIMESTONE FOSSILS—Continued.

Brachiopods. Figs. 1-19.

- Figs. 1, 2. *Schizophoria propinque* Hall.
 Figs. 3, 4. *Stropheodonta perplana* (Conrad.)
 Figs. 5, 6. *Productella spinulicosta* Hall. Usually this fossil shows long spines projecting from the surface. This genus differs from *Productus* of the later formations, in that it has hinge teeth. The genus makes its first appearance in the Middle Devonian.
 Fig. 7. *Stropheodonta hemispherica* Hall.
 Fig. 8. *Reticularia fimbriata* (Conrad). The fimbriate structure shows up nicely under a magnifying glass.
 Figs. 9, 10. *Chonetes mucronatus* Hall. Note the spines projecting from the pedicle valve along the upper margin of the cardinal area.
 Fig. 11. *Atrypa reticularis* (Linnaeus).
 Fig. 12. *Pholidostrophia iowaensis* (Owen).
 Figs. 13, 14. *Spirifer gregarius* Clapp. A common fossil in this formation. About thirty-two feet below the "bone-bed," it occurs in great numbers.
 Figs. 15, 16. *Spirifer duodenarius* (Hall). This fossil occurs only in the upper part of the formation in central Ohio. It, as also the preceding, belongs to the primitive simple plication type of *Spirifer*.
 Fig. 17. *Meristella nasuta* (Conrad). A smooth spire-bearing shell, which occurs most abundantly in the lower part of the chert zone.
 Figs. 18, 19. *Spirifer acuminatus* (Conrad). This *Spirifer* is almost entirely limited to the upper part of the formation in the region here discussed. Note that its costae or ribs bifurcate, a characteristic of the more advanced species of the genus.



Columbus limestone fossils.



PLATE X.

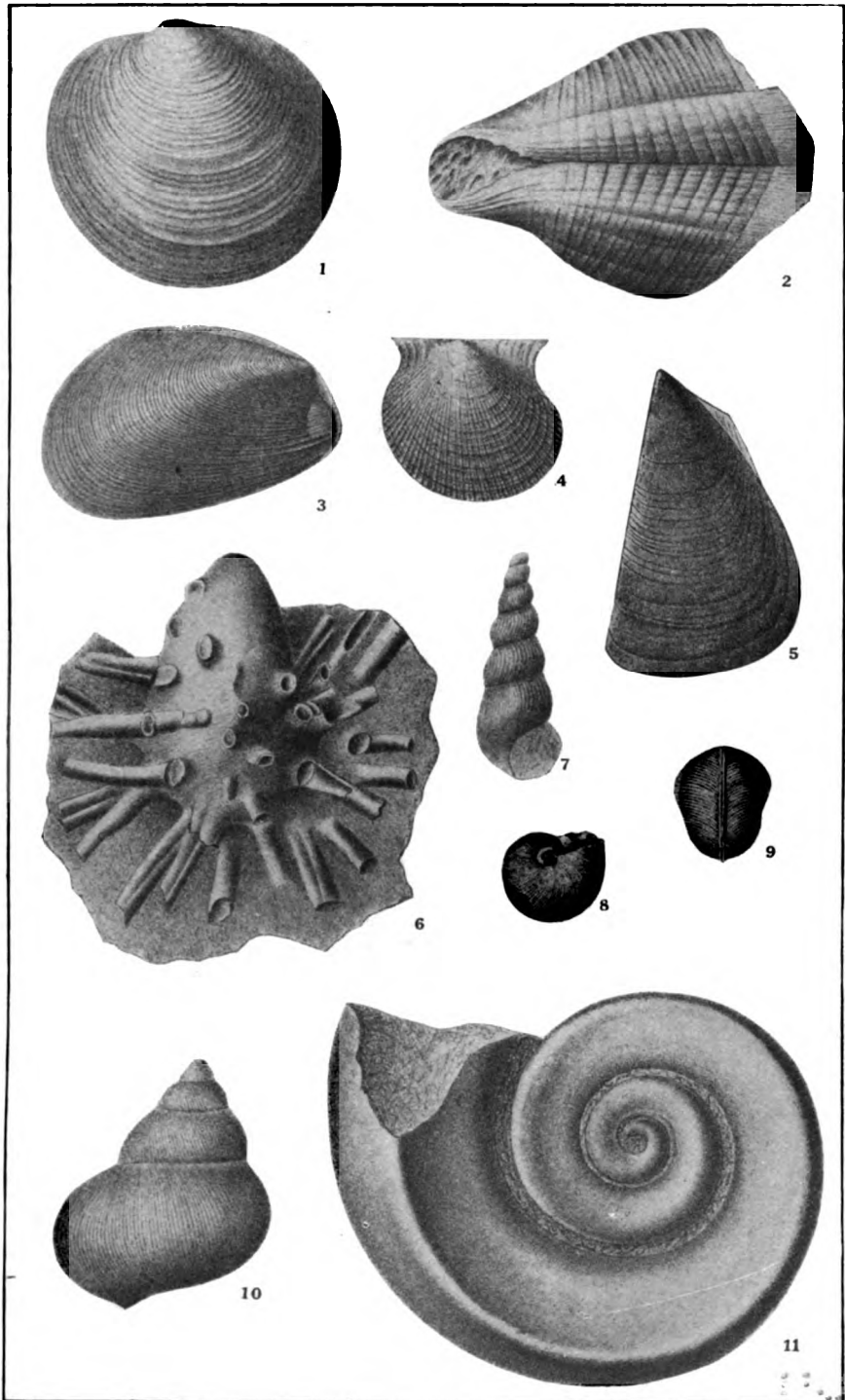
COLUMBUS LIMESTONE FOSSILS—Continued.

Pelecypods. Figs. 1-5.

- Fig. 1. *Paracyclas elliptica* Hall. This is a common and easily recognized fossil, occurring throughout the formation.
- Fig. 2. *Conocardium cuneus* (Conrad). This fossil usually occurs as merely a cast of the interior of the shell. It is one of the most striking fossils of the formation.
- Fig. 3. *Modiomorpha concentrica* (Conrad). Note the concentric marking of the surface, which has given the specific name.
- Fig. 4. *Aviculopecten cleon* Hall.
- Fig. 5. *Mytilarca percarinata* Whitfield. This is not a common, but a very characteristic fossil.

Gastropods. Figs. 6-11.

- Fig. 6. *Platyceras dumosum* Conrad. Note especially the spines which cover the exterior part of the shell. It is a common fossil just below the "bone-bed."
- Fig. 7. *Loxonema pexatum* Hall.
- Figs. 8, 9. *Bellerophon pelops* Hall. Note that this shell is coiled in a single plane. Usually found as a cast of the interior.
- Fig. 10. *Callonema bellatulum* (Hall). These last three are excellently preserved in the cherty layers of the Columbus limestone. Even the smallest exterior markings of the shell show nicely.
- Fig. 11. *Pleuronotus decewi* (Billings). A very common cast in this formation. It is rarely preserved with the shell, and yet it is quite readily recognized. The coil is nearly in a single plane.



Columbus limestone fossils.

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PLATE XL.

COLUMBUS LIMESTONE FOSSILS—Continued.

Pteropod.

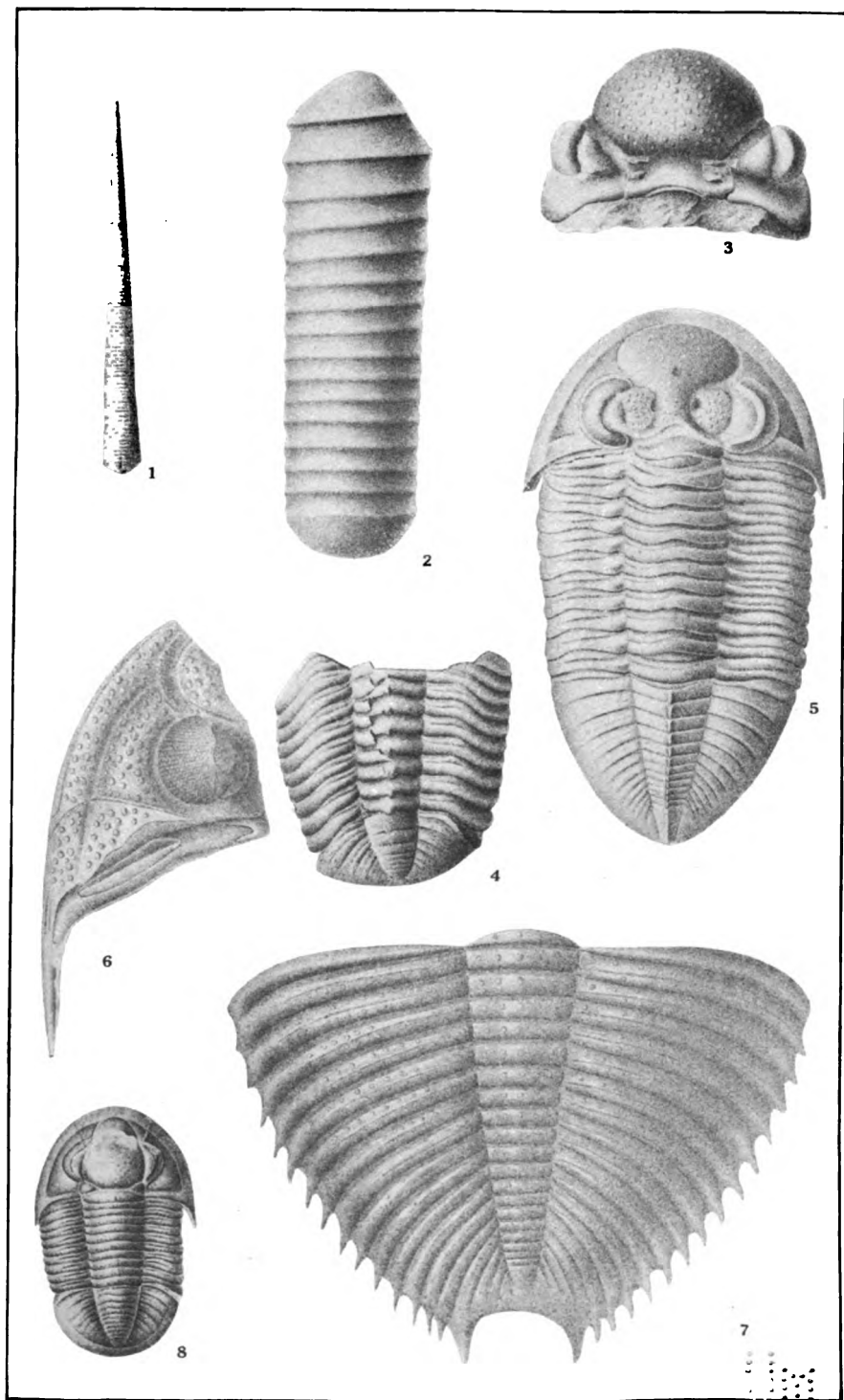
- Fig. 1. *Coleolus crenatocinctus* Hall.

Cephalopod.

- Fig. 2. *Spyroceras thoas* Hall. One of the straight Orthoceratites, which are quite abundant in some parts of the formation.

Crustaceans (Trilobites). Figs. 3-7.

- Figs. 3, 4. *Phacops cristata* Hall. Usually it is only the pygidium of the trilobite that is found. The four species figured on this plate are quite common.
- Fig. 5. *Chasmops calypso* Hall.
- Figs. 6, 7. *Coronura diurus* (Green).
- Fig. 8. *Proctus rowii* (Green).



Columbus limestone fossils.

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PLATE XII.

DELAWARE LIMESTONE FOSSILS.

Brachiopods. Figs. 1-17.

- Figs. 1, 2. *Orbiculoidea lodiensis* (Vanuxem).
Fig. 3. *Lingula manni* Hall. These two fossils occur in the shaly basal portion of the formation. Their shells are composed of phosphate of lime, as is so frequently the case in shells occurring in black shale.
Fig. 4. *Lingula ligea* Hall.
Fig. 5. *Rhipidomella vanuxemi* Hall.
Fig. 6. *Stropheodonta demissa* (Conrad).
Figs. 7, 8. *Leiorhynchus limitare* (Vanuxem). This is a characteristic fossil of the Marcellus shale.
Fig. 9. *Leptaena rhomboidalis* (Wilckens). This species, as at present defined, is one of the long-lived forms. It is found from the Trenton to the Waverly, but there is a difference in the forms from the two extreme ends. These, however, seem to grade into each other.
Figs. 10, 11. *Delthyris consobrina* (d'Orbigny). A common fossil of the formation. Note the zigzag concentric markings; unfortunately, these seldom show in specimens from the limestone.
Figs. 12, 13. *Martinia maia* (Billings).
Figs. 14, 15. *Chonetes deflectus* Hall. Compare this with the *Chonetes* figured among the Columbus limestone fossils.
Figs. 16, 17. *Cyrtina hamiltonensis* Hall.

Pelecypods. Figs. 18 and 19.

- Fig. 18. *Pterinea flabellum* (Conrad).
Fig. 19. *Grammysia bisulcata* (Conrad). Note the ridge, with a furrow on either side, running from the beak to the margin.

Gastropods. Figs. 20 and 21.

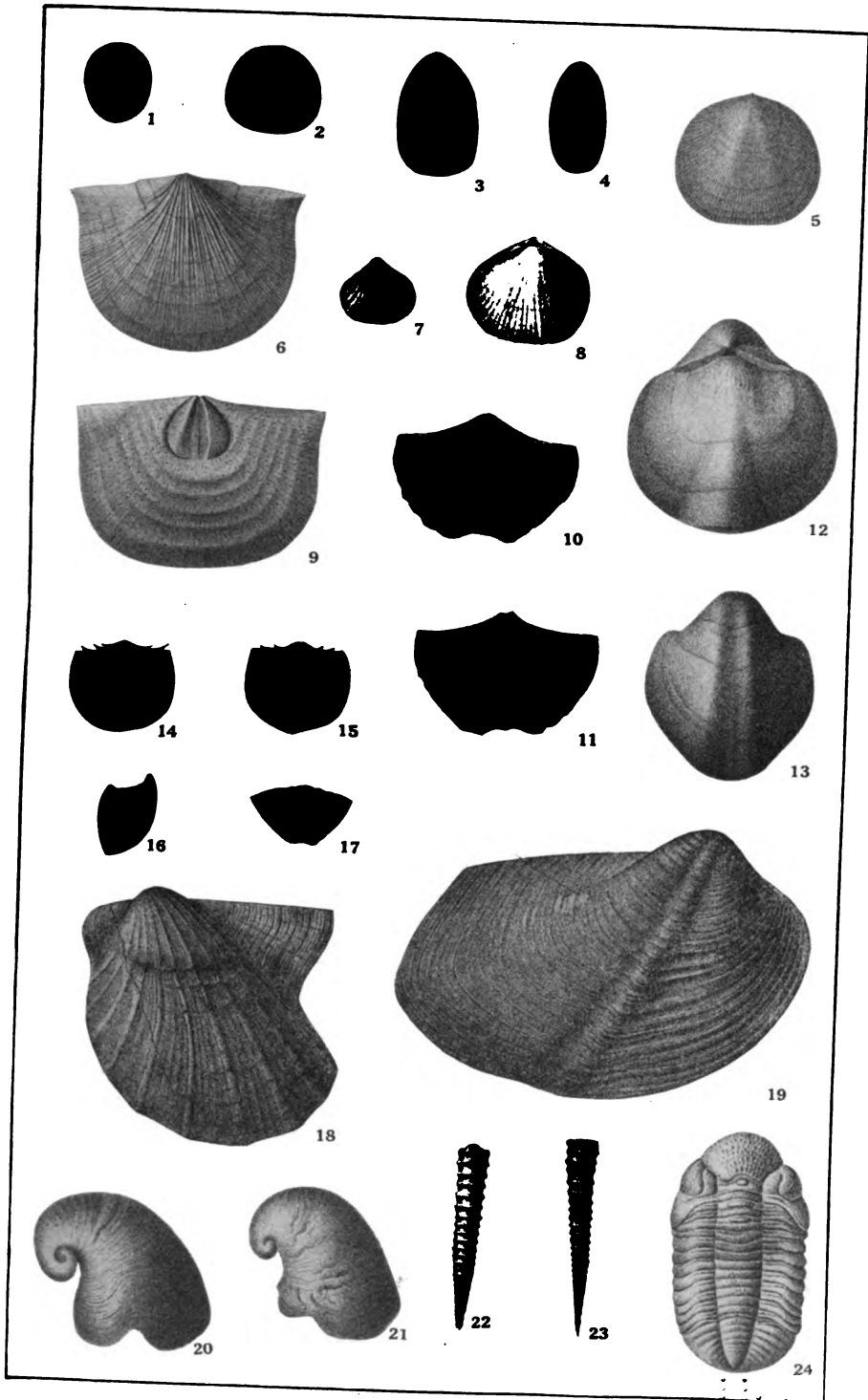
- Figs. 20, 21. *Platyceras erectum* (Hall). Compare this species with the spiny one occurring in the Columbus limestone.

Pteropod. Figs. 22 and 23.

- Figs. 22, 23. *Tentaculites scalariformis* Hall. This fossil is very frequent and readily recognizable. It is probably a worm tube.

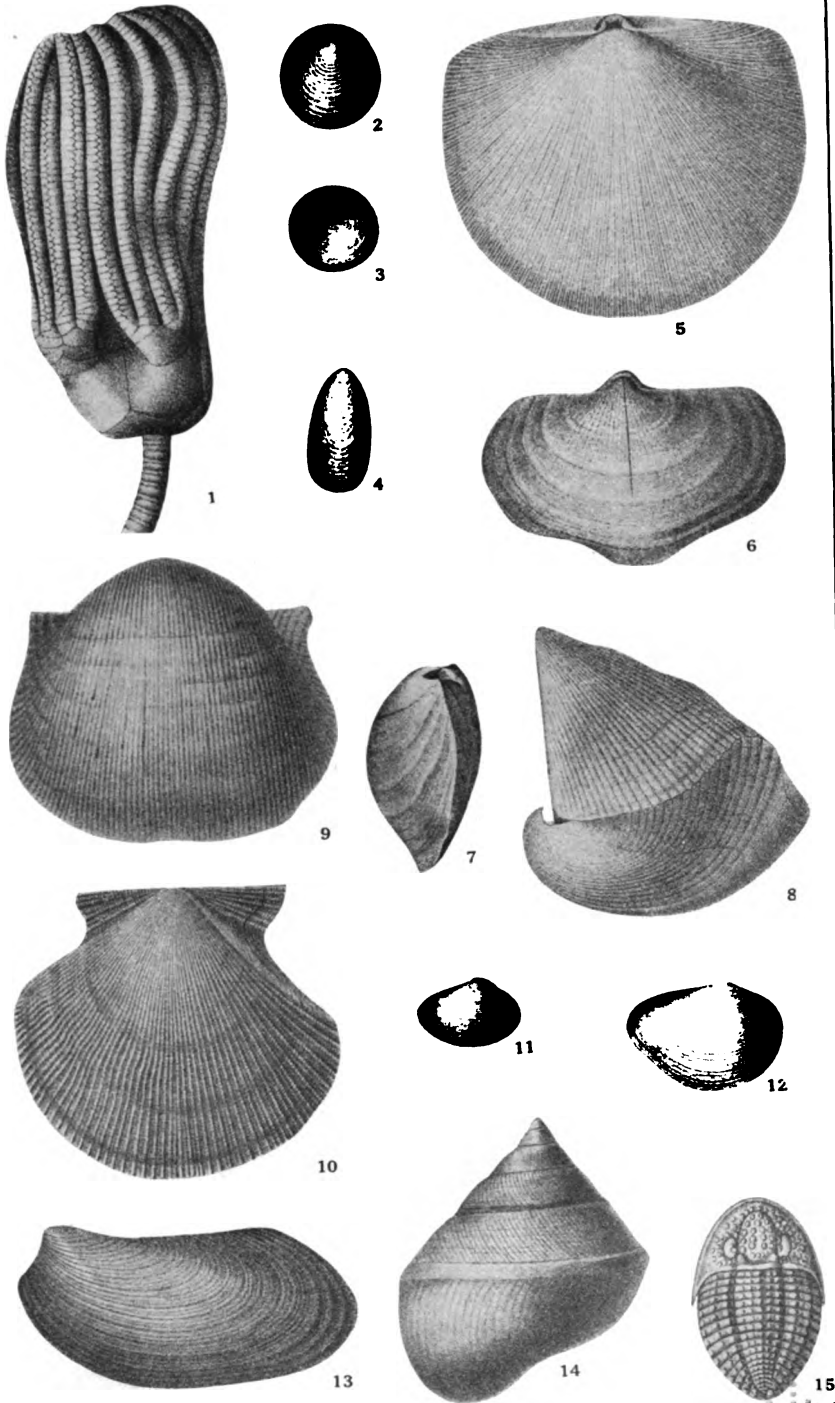
Crustacean (Trilobite). Fig. 24.

- Fig. 24. *Phacops rana* (Green).



Delaware limestone fossils.





Waverlyan fossils.

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PART II.
PHYSIOGRAPHY OR SURFICIAL GEOLOGY.

By **GEORGE D. HUBBARD**

CHAPTER II.

LOCATION.

Physiographically the area around Columbus included within the scope of this bulletin belongs to that regional province known as the Prairies. Nevertheless, the topography of the region lacks the variety of feature, the rolling surface with sag and swell or with hillock and kettle containing swamp or lake, so constant over broad reaches of these drift prairies. In the early days it differed from much of the prairies in being rather completely timbered. Further, the area is located near the eastern border of the prairies, so near in fact that the southeastern corner comprising some twenty-five square miles, shows the effects of the more resistant rocks of the Allegheny Plateau, and presents rock hills. A similar effect, in higher land but not hilly, is found continuously from Pickerington northward to the limits of the area, in a belt four miles wide at Reynoldsburg and over seven miles wide at New Albany. The highest of this land is about two hundred feet above that lying to the west with well-marked west-facing slopes and occasional bare "brows" of rock between, but no escarpments.

The drift border lies nearest to Columbus on the southeast. While the area lies from fifteen to sixty miles northwest from the drift margin, it is near enough to be in the zone of thick accumulation, and it has received a heavy mantle of till transported by the continental glaciers of the recent ice age from many points to the north, even as far as Canada. With this great depositional work, probably, as may be shown later, very little ice erosion was accomplished. While the thickness of the drift varies greatly, its surface is so evenly disposed that aside from one large moraine, almost the whole area may be called a till plain of remarkable levelness, broken only a little by very moderate, postglacial, stream erosion.

GENERAL DESCRIPTION OF TOPOGRAPHY.

The Drainage Pattern.—On the topographic map the most striking feature is the north-south alinement of streams, valleys, and interstream areas. This was noted in one of the earliest descriptions

of Franklin County physiography,¹ and has not ceased to call forth comment. It is perhaps the most perfect part of a similar alinement of streams over several neighboring counties.

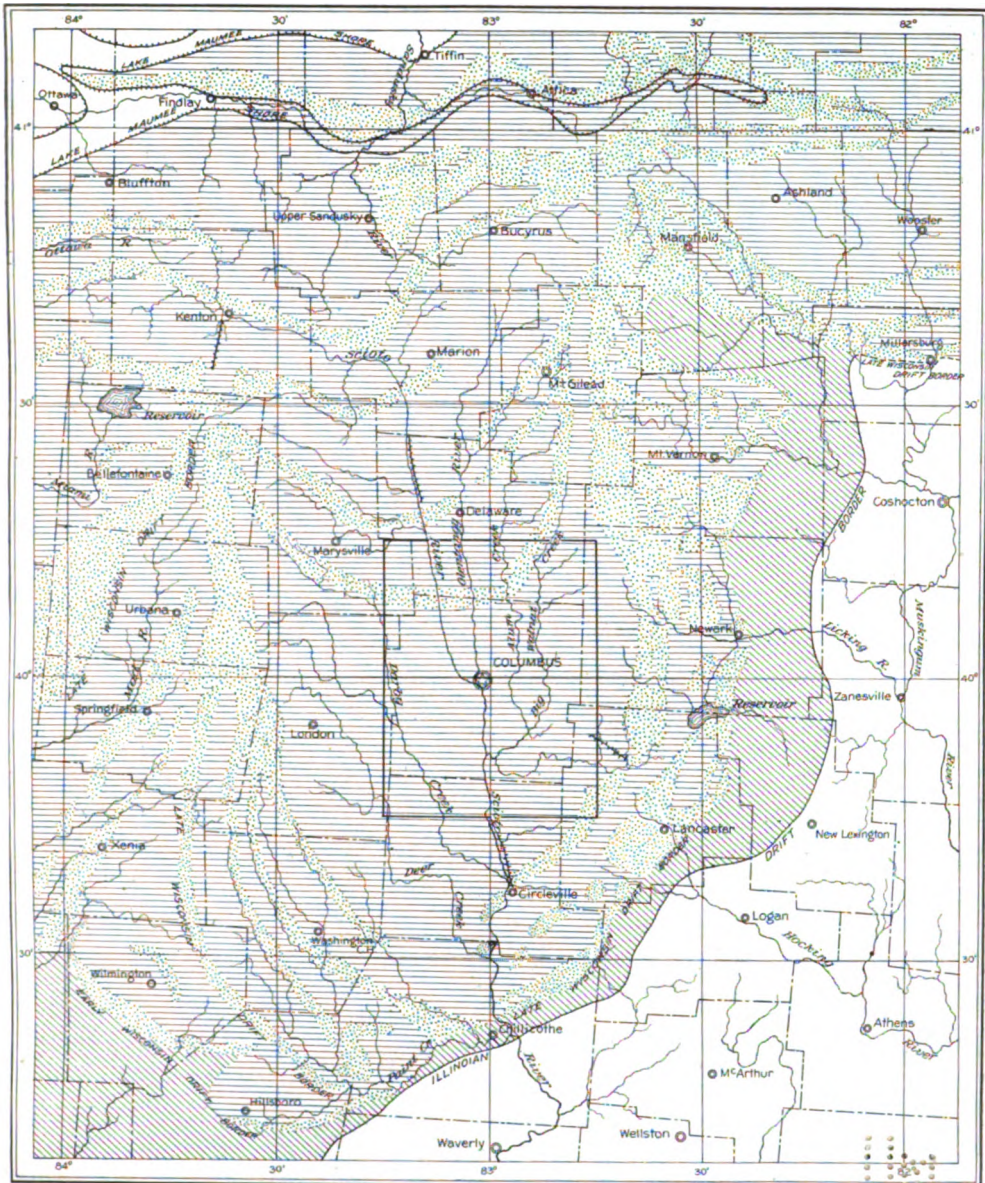
In the northern part of the area there are four, nearly parallel, south-flowing, slightly-converging streams, and two others, one on each side of the four, just beyond the limits of the quadrangle. Between these six streams extend five strips of inter-stream plain. Several of the railroads, in accord with these features, enter Columbus from the north, along these elevated tracts. Adopting the names of small towns upon them, the several level-topped areas between the streams may be designated from west to east as the Hilliards, Powell, Worthington, Westerville and New Albany strips.

In the southern part the alinement shows less clearly. This part is bisected by the Scioto and its western half is, in the main, a continuation of the Hilliards strip; but, owing to the fact that the downstream convergence of the valleys has brought the Darbys within the area, a considerable tract of another strip between them and Deer Creek is included in the quadrangle. Since the Olentangy River enters the Scioto, the Powell strip runs out at their junction. The Worthington strip is cut off at the south by the Big Walnut as it swings westward and joins the Scioto after receiving Alum Creek from the right side and Blacklick from the left. In a similar manner the Westerville strip is terminated southward by the junction of its bounding streams. The New Albany strip, split in its southern part by Blacklick, may be thought of as continuing southwestward beyond the mouths of Alum Creek, Blacklick and Big Walnut off the area, and bounded on the southeast by Little Walnut which cuts around the small, hilly tract in the corner referred to in the first paragraph.

Minor Lateral Valleys.—These major water courses mentioned above are for the most part, consequent streams on the till plain, and they date from the last retreat of the glacier from the region. It will be shown later that none of them can claim, at least to any significant extent, a preglacial ancestry. Many lateral minor valleys, developed by subsequent streams, join each of these major valleys, descending in the northern part as rock gorges from the interstream remnants of the till plain, 100 to 200 feet, to the floors of their masters; but wandering in the southern part as shallow, youthful, drift valleys because here the till plain is much lower with reference to the Scioto than farther north.

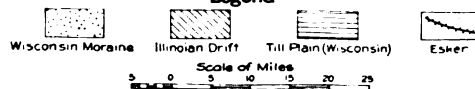
The lateral valleys are undoubtedly the most valuable criterion for measuring post-glacial time, because the majors were well under way when the ice was finally melted, having been initiated by the drainage attendant on the melting of the ice. In many of the tributaries of the

¹ Orton, Edward, *Geol. Survey of Ohio*, vol. 3, pp. 596, 597.



MAP OF THE SCIOTO GLACIAL LOBE
(AFTER LEVERETT)

Legend



Moraines of the Scioto Valley Lobe. Note the loops festooned from the highlands on either side with till plains between. The Columbus area is located.
(After Leverett, Mon. U. S. Geol. Surv., No 41, Pl. XIII.)

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Scioto, particularly on the right or western side, are waterfalls over ledges of the heavy-bedded limestone already described as underlying this part of the area.¹

The Moraine Pattern.—Crossing this conspicuous, approximate parallelism is a weaker but equally significant concentric pattern consisting of purely glacial features. It was stated on a previous page that almost the whole area might be called a till plain. Indeed, it is a part of one of a series of similar crescentic till plains, alternated with a series of concentric recessional moraines, convex toward the south, and festooned across the central part of the State from the highlands near Bellefontaine to those near Mt. Gilead and Mansfield. A clear conception of this concentric arrangement of features can be obtained by consulting the map, (Pl. 14), which is reproduced from Leverett's² exhaustive treatise on the glacial features of the Ohio and Erie Basins.

One of the larger moraines shown on this map, and designated the Powell, sweeps across the area from Sunbury and Galena in the northeastern part, southwestward nearly to Westerville, then it bears more nearly westward, where it is crossed by Alum Creek and Olentangy River just north of the Franklin-Delaware county line, and by the Scioto on the same line southwest of Powell. From this point it bears a little northwest in a broad belt to New California and far beyond the confines of the quadrangle. South of this large moraine and somewhat concentric with it, may be traced other much smaller, less continuous, belts of moraine as shown on the physiographic map. (In pocket.)

Glacio-Fluvial Features.—Associated with these moraines are two types of features. On their convex or southern sides are some minor outwash deposits, and within their concavities are several interesting eskers. Tumuli of till, sand and gravel occur in considerable numbers over parts of the till plain, but they do not in any manner seem to conform to the concentric pattern. A large kame area consisting of a pile of gravel hills about four miles south from the city limits of Columbus, is adorned by the uniformly red and white buildings of the Hartman farm. Several kame areas will be described subsequently with the other glacial features.

Rainfall and Runoff.—Since it is the rainfall which perpetuates the streams and keeps them at their perennial task of reshaping and removing the lands, it may be well here briefly to describe the rainfall and some related topics. The total precipitation in Central Ohio including all rain, hail, sleet and snow, amounts to about 40 inches each year, or enough to make a layer of water all over the area three and one-

¹ Chapter I, p. 19.

² Leverett, Frank, Mon. U. S. Geol. Survey No. 41, pl. XIII.

third feet deep. Probably not more than one-third of this runs off; but it is this third which carves the valleys, carries the waste away and delivers it to the larger streams or builds it into such minor features along the valleys as alluvial fans and flood plains.

Of the portion which soaks into the ground, a small part is collected in cracks in the rocks or in more or less porous layers above relatively impervious ones, and thus conducted again to the surface along valley walls, as seepage, or, if the latter be concentrated, as springs forming streams. Most of this water coming out as seepage or springs ultimately gets into the streams, so it assists in erosion and transportation.

A small portion of the water which falls as rain is collected in basins on the surface and thus keeps a few tiny lakes and swamps in existence. If it were not for these basins and for the almost continuous vegetation cover, maintained by the precipitated moisture, a cover which prevents much water from running off, the streams would carry away a much larger proportion of the rainfall and with it much more rock waste, and erosion would certainly be greater. This assumption is on the ground that the precipitation remains the same.

CHAPTER III.

PHYSIOGRAPHIC HISTORY.

PRE-WISCONSIN WORK.

Although to the casual observer practically everything seen in the Columbus quadrangle may seem to date from the melting of the great glacier, the history of the features just described began ages before the time of the coming of the ice, just as American history has its roots far back in the nations of Europe, although the first settlements were made here only 300 to 350 years ago.

The development of the present features depends partly upon the rock structures underneath, and partly upon the treatment those structures have had through millions of years at the hands of weather, glacier, and stream.

For a full and adequate description of the rocks, their origin, position, structure, and strength, the reader is referred to the chapter¹ dealing with the geology of this region. Their modification by the various physiographic agents, from the time they were made, down to the present, in so far as the changes have contributed to the present topography, will now be examined. Some of the record is deeply buried beneath the glacial drift, other parts have been mutilated in bringing about later changes; therefore many points are in obscurity and some are today entirely out of our reach. In some cases the incompleteness of the obtainable record may lead to wrong conclusions, hence great care should be exercised in interpretation.

PREGLACIAL TOPOGRAPHY.

Without endeavoring to present the argument all the way through, it may be stated that the area under discussion had been subjected to subaerial conditions of weathering and stream work from before the close of the Paleozoic era down to the Glacial period. During this time there had been oscillations of level and climatic changes. The land had been roughened by erosion, valleys had been carved, widened and deepened, tributaries developed and divides reduced until the whole region had passed from physiographic youth, through maturity, to old age. This process was probably repeated more or less completely more than once, so that just prior to the coming of the glacier, the country presumably had been reduced from a low plateau to a lower, grandly rolling surface deeply mantled with residual soil and subsoil.

¹ Chapter I.

Evidence in the Field.

The rolling topography of large pattern may be found, modified to some extent by ice erosion, in the large features of the present rock topography. To appreciate it one must necessarily pass over many local steep slopes, which will be treated later, and examine only the general or larger features.

Gentle Slopes.—A few local examples of the slopes referred to under the heading "grandly rolling" will suffice to make the meaning clear. Lithopolis in the southeast lies among the hills. A couple of miles to the east and southeast of this village is Chestnut Ridge, a crest with neighboring hills all of sandstones and sandy shales. The highest rock surface among these hills rises to about 1,150 feet; to the north and west the slopes descend from the crest at the rate of about 100 feet to the mile, and the rock surface drops from this summit altitude to 800 feet in three miles northward, to 750 feet in four miles northwestward, and to 760 feet in five and one-half miles westward. Such slopes make an angle with the horizontal of about one degree.

*Other examples from the southwestern part of the area are added. At Derby, wells strike the rock at a depth of 130 feet, which places the rock surface about 780 feet above sea level. (Pl. 15.) Around Harrisburg, the stream has revealed it in several places, ranging from 800 to 780 feet above sea level. Southeast of Harrisburg, some five miles, and one mile southwest of Matville, the rock is less than 690 feet above sea level. A mile nearer Harrisburg, it is 100 feet higher. This lowest altitude is fifty feet below the lowest bed of the channel of Big Darby on the area.

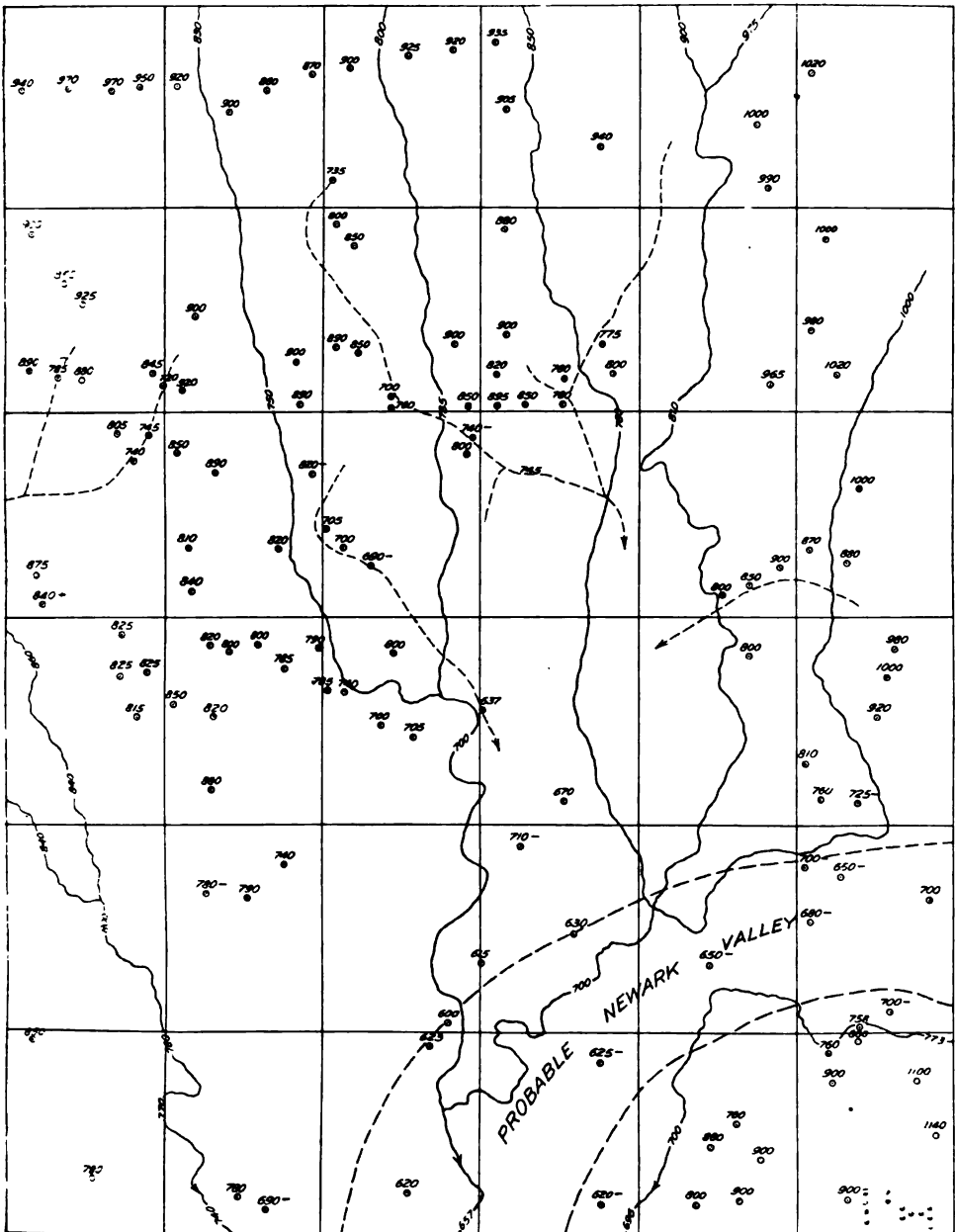
At Rome, on the National Pike, a few miles west of Columbus, the rock surface is 820 feet high and is covered with over 100 feet of drift. Two miles south of Rome, the rock is 880 feet high, while two and three-fourths miles farther southeast toward Grove City, it is only 740 feet above sea level. (Pl. 15.) The Scioto south of Columbus nowhere encounters rock, therefore, all along the river the rock surface is less than 700 feet above sea level, and at the edge of the area less than 660 feet.

Rarely are these slopes of the rock surface as great as 50 feet in a mile, but they are greater than the slopes of the till plain except where it has been modified by post-glacial erosion. Instances with the same values might be multiplied from other parts of the quadrangle.

Steeper Buried Slopes.—Besides these long gentle slopes which must have required ages to make, well records and gorge wall outcrops reveal many ancient, steep rock-slopes and a few valleys comparable with the present steep-sided gorges. Some of the more marked instances found are added. A little over a mile north of Amlin are several wells along the east and west road whose depths make known much of the rock topography. The first one on the west end of the series shows the rock surface to be less than 760 feet above sea level; the next one an

*Text in smaller type consists of additional examples similar to those previously given, or of somewhat elementary matter, which may be familiar to many readers. It is believed that all fine print may be omitted without breaking the continuity of the report.

PLATE XV.



Rock topography beneath the drift. Figures give the altitude of the rock above sea level for the place indicated by the circle. Solid lines show present major streams and figures in these lines altitude of stream bed regardless of material. Supposed buried valleys shown with broken lines. Probable Newark Valley between two heavy dash lines in southeastern part. Altitudes given with a minus sign are maxima, the rock not having been reached.

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eighth of a mile away, and across the road, shows the rock surface at 803 feet, while another about a half mile east shows 845 feet. One-eighth of a mile farther east the rock surface is 720 feet high and less than one-third of a mile still farther east it is 920 feet. Here is a valley less than a half mile wide with an east wall 200 feet high and a west wall of at least 125 feet, with slopes of 1 in 7 or 8, and 1 in 5 respectively (Fig. 5). It is manifest that these cannot belong in the same cycle with the very gentle neighboring slopes, and also that there should be no such slopes and valleys in immediately preglacial topography which had been so long in developing. Their presence testifies to a short erosion period following the long one which antedated the laying of the last drift, and also to only moderate glacial erosion after they were made else they would have been rubbed away.

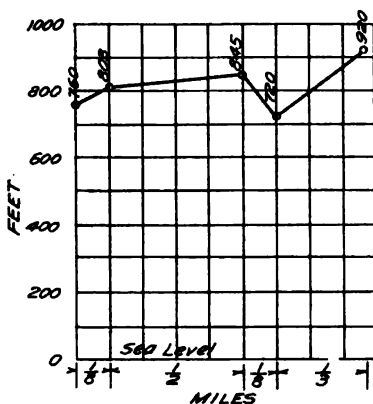


Fig. 5—Section across a buried valley near Amlin. Datum line sea level. Altitudes in feet. Horizontal distance one and one-eighth miles.

Evidence From More Distant Topography.—Further evidence regarding the nature of the preglacial topography of Central Ohio may be had by consulting the topography of southern central Indiana and adjacent parts of Kentucky. Near Tell City, Indiana, and Owensboro, Kentucky, the underlying rock is a series of not very resistant formations, horizontally disposed, and the topography has not been glaciated but the area has been subjected to erosion, as had this of Ohio, through long ages of time and presumably with similar oscillations of level and fluctuations of climate. The slopes are all very gentle, flood plains broad even up the third and fourth order branches; the divides are rows of rolling hills or short, low ridges, rising a hundred feet or a little more above the flood plains. The latter occupy something like half the area. The strongest slopes are 100 feet in about a half mile, but most of them along the divides require a mile or more to make such a descent. There are no gorges nor youthful valleys of any sort. This condition was essentially reached before the glacial period, because there has not been time enough for much change on mature topography since the ice invasion. Such old age as here described must resemble closely in its main features the topography of the Columbus region before the advance of the ice. The steep slopes found may be interglacial, or may be related to the oncoming ice as shown in subsequent pages.

These conclusions as to the character of the immediately preglacial

topography are in harmony with the long period of atmospheric erosion which is known to have continued from the close of the Paleozoic era to the beginnings of the Glacial period.

THE EARLY CONTINENTAL GLACIER AS A PHYSIOGRAPHIC AGENT.

A continental glacier is a large ice cap consisting of snow, modified by pressure and compression, and by repeated partial melting and re-freezing.¹ It usually occurs on a plain or plateau, rather than among mountains, and spreads laterally, overflowing neighboring lands. The thickness is hundreds of feet, and, back some miles from the margin, may be a few thousands of feet. The movement is outward from a central area, approximately radially, but varying in response to topographic irregularities. The margin of these huge ice sheets is usually more or less lobate in response to broad inequalities in the elevation of the land over which they spread.² Over broad lowlands between higher, a lobe advances. Forward creeping is much more active on the warmer, or low latitude side, where opposition to advance is perpetually removed by melting. Although the movement is very slow it is very powerful owing to the size and weight, and for this reason a glacial invasion may mean much physiographically to a region.

Repeated advances and retreats (or meltings) of the glacier are believed to have occurred at long intervals over a considerable portion of the North American continent. At least two of these are recorded in Central Ohio which have been called the Illinoian and the Wisconsin.³

We have seen in previous paragraphs what manner of topography the ice over-rode on its first invasion of the Columbus quadrangle. The ice sheet entered from the north, presumably in a great rounded scallop known as the Scioto lobe (Pl. 14), and so spread as to occupy the space between the hills near Bellefontaine on the west and the highlands from Mansfield southward to Newark, Carroll and Chillicothe on the east. It may have been so thick as to cover many of these hills at times, and certainly completely covered all intermediate lowlands. Where not over-ridden again by later ice, the presence of old drift would help to determine which hills were covered by the first glacier.

Effects on Plants and Animals.

As the glacier slowly pushed on southward spreading over the broad lowland, it over-rode everything that could not migrate, including of course all plants, trees and forest, bearing them down to the ground and mixing them in with the waste and ground rock which the ice moved forward. All animals which could migrate most likely did so, not as individuals but perhaps as a species through a series of generations. Each generation was more restricted in its roaming on the northern side of its home than was the former, and each new home was placed farther south than that of the year before. There must

¹ Chamberlin, T. C., and Salisbury, R. D., *Geology*, vol. 1, pp. 308-317.

² Leverett, F., *Mon. U. S. Geol. Survey No. 41*, pp. 222-226. Carney, F., *Jour. Geol.*, Vol. 15, 1907, pp. 488-495.

³ *Bull. U. S. Geol. Survey No. 58*, pp. 14, 15. Leverett, F., *Mon. U. S. Geol. Survey, No. 41*, pp. 50, 51, 228 f.

have been also a migration of plants. The ice front may be said to have *crept* southward over the area, and possibly with an intermittent advance, interspersed with halts when the melting just equalled the progress of the mass, or with recessions when the melting exceeded the movement forward. But in the aggregate the front of the ice made progress and advanced over the area.

Effects on Streams.

Streams that were flowing away from the glacier would receive water from the melting of the ice and would be increased in size. They would also receive rock waste freed from the melting ice, or washed in by the ice-born drainage. If this waste exceeded the power of the augmented streams to carry, it would be laid along the valleys aggrading until the stream could carry what was left. It is probable that much gravel and sand was thus laid along the old valleys by the streams of low grade. Many of the deeper well records mention gravel and sand near the bottom. Several such did not strike rock until below the present levels of the streams.

About three miles north of Linden, opposite the country schoolhouse, is a well 145 feet deep, which ended in gravel and sand of a bluish unweathered character, without striking rock at all. The depth reached here is 25 feet below the stream bed in Alum Creek two miles east. A test well for oil was sunk a few years ago in the Alum Creek flood plain at the point referred to above, and rock was struck at a depth of 24 feet below the stream, after passing through gravel. A group of deep wells occurs some three miles west of Clintonville, along the divide between the Scioto and Olentangy rivers, several of which encountered gravel near the bottom. One of these reached a depth of 170 feet and ended in gravel without striking rock. The bottom of this one is 30 feet below the channels of both the Olentangy and the Scioto at the nearest points. These gravel deposits may be some that were laid in the valleys by the waters from the oncoming ice. Old, weathered, and often cemented, gravels are found below the fresh ones along the east bluff of the Scioto in the southern part of Columbus, which are probably to be correlated with those referred to above or with outwash of Illinoian age.

Turning now to streams which were flowing toward the approaching ice it must be seen that their difficulties would be quite different. Their valleys would be filled with waste, and by the ice itself, until flow in the normal direction would become impossible. The water would then accumulate as a long lake in the valley, until its level equalled that of some low divide at the head of the main stream or some tributary, when overflow would begin at the lowest place. Water thus flowing over the col in the divide would lower it at least through the thick mantle, possibly in some places into the rock, and this together with aggradation along the bed of the long lake might make it easier for the stream to continue in its new course than to resume the old one when the ice melted out. If the ice, after interfering with drainage beyond its margin in this way, continued to advance over the reversed

stream and the notched divide, mantling all with drift before or after rounding the features by erosion, it might be difficult to find the old col, the new valley, and the broad, mature preglacial valley. Possibly some of the gorge-like valleys found with old drift in them, and steep slopes with old drift banked against them (p. 56), may have originated in this way. In some instances streams flowing eastward or westward might be modified somewhat as here suggested for north-flowing streams.

That this hypothecated ponding actually did take place within this area is shown in two instances. There are great quantities of lake clays exposed in the Glenmary Run both west of the road on the north side of the stream, and east of the road below the trestle, in the ravine behind the schoolhouse, up the east branch and several of its tributaries, and up the eastern tributary of the north branch, which enters the latter near the north dance hall. Some of these clays are blue with small, button-like, calcareous, clay concretions; others are yellow with ferruginous, clay concretions; both are profusely jointed and in some places quite sandy. The distance across this lake as far as now determined, is at least a half mile north and south and nearly as broad east and west. The sediments rest on the rock at an altitude of 820 feet above sea level near the trestle and their upper surfaces have been seen at as great an altitude as 890 feet, hence the thickness may be assumed to be as great as 60 to 70 feet. In at least three places the characteristic blue, hard, jointed, boulder clay was found above the lake beds which must establish their age as pre-Illinoian. Additional evidence to fix their age is found in a dark soil at one place on top of the old drift, with new drift capping the soil (p. 66). The second example of stratified clays made at this stage was found one-half mile up the run from the sandstone quarry northeast of Reynoldsburg. A tough, plastic, blue clay, carrying many common Pleistocene shells occurs at the water level and shows below water. Its upper surface, two feet above water, is beautifully ripple-marked, and dips gently southeast. Above the clay is two or three feet of blue, hard jointed, pebbly drift containing clay concretions.

A good example of a filled young valley containing old drift is cut across by Rocky Fork a mile and one-half east of Gahanna just beyond the suspension bridge. Here the Bedford shale stops with a strong south or southeast facing slope and old drift may be seen piled against it some fifteen feet high, above which is 25 to 30 feet of later drift, a part of which is stratified. Between the drift and the bed rock is talus of uncemented fragments of Bedford shale without admixture of drift. (Pl. 16A). This steep slope may not have been formed in the manner outlined above but the evidence shows that at least two ice advances have occurred since it was made. A fuller discussion will be given later (p. 69).

Beyond the margin of the ice sheet are found many illustrations of this type of drainage modification, left uncovered and free for careful investigation. Their presence, like that of the outwash, constitutes one of the tests for judging that the region has been approached by a glacier.

Effects on Mantle.

As has been shown this region is believed to have been deeply mantled with residual rock waste in preglacial days. Only one exposure

of residual waste beneath the old drift was found. This particular case occurs in the northwestern part of the quadrangle, in a small run leading eastward from Hyattsville about one-half mile from the station. The section is as follows:

	Feet.
5. Loose, fresh yellow till.....	6-8
(More in the grassed, gentle slope above).	
4. Blue, hard, jointed till (apparently old—Illinoian).	6
3. Stratified sand, much weathered; thickness variable	2+
2. Hard, rusty, jointed dark material without foreign admixture, probably an old soil grading into No. 1.....	2
1. Ohio shale, firm and strong at water, but weathered above; grading into No. 2	2-5

In all other cases when the old drift is found, either it lies on fresh rock or its contact with the rock is covered. Since at least 75 exposures of probable old drift below new have been noted in this area and only in this one exposure was residual waste seen beneath any of them, it would seem that the removal of the mantle by the earlier ice invasion was more complete than that by the last. At several points residual rock waste was found immediately beneath later fresh drift, showing that the later ice erosion was sufficient to remove the old drift but not the old waste down to the rock.

Effects on Rock Topography.

It has long been granted that ice containing tools in the form of pebbles and boulders, has power to erode rock. Moderately loaded ice with thickness to give it sufficient weight, and capable of considerable movement is a very active eroding agent. Probably the most convincing arguments for ice erosion in this sense, which are found in this area are (a) the pulverized but undecayed rock in the drift, (b) the smoothed, striated, grooved or furrowed rock surfaces and (c) the sharp contact between freshly smoothed rock and the drift at almost all points. This last argument means ice erosion enough to remove most of the effects of previous weathering, and was discussed in the last topic.

Undecayed Rock Fragments.—Two simple tests for pulverized rock can be made. First, ground rock fragments can be seen with the lens. Second, a carbonate reaction with hydrochloric acid applied to drift means undecomposed limestone.

Striations.—Observation in the field is the basis for the second argument. Striated and smoothed surfaces are occasionally found. If ever made on any rock beside the limestone, they have been weathered out and are gone. About three miles northwest of Rathbone the harder limestone presents very nice striations whose direction was

determined by means of a compass to be S. 60° to 70° W. They run over a rock ridge summit which rises here almost through the drift and is quarried at several places. At another point on the east bluff of the river nearly opposite the mouth of Hayden's Run are nicely striated surfaces. Again on the west side of the Scioto River between it and the Toledo and Ohio Central railroad just as the latter swings away from the bluff some four miles out from the station, others occur under fresh drift with the direction S. 17° E. The fourth place is a finely exposed surface cleared for quarrying near the southwest edge of the quarries west of the Scioto River and south of the Pennsylvania railroad tracks at Marble Cliff. Here the direction determined was S. 12° E. No corrections are needed, for the line of no magnetic declination passes very close to Columbus. These four localities are believed to be all new ones, and, except the first, agree well with previous finds.

In each of the four cases above, the glacial striations are on solid unweathered limestone surfaces from which all evidence of rock decay had been removed previous to or during the making of the grooves. No weathering adequate to remove or scarcely to weaken them has taken place since their carving.

Solution Cavities in the Rock.—Rather striking contributions to the question of the measure of modification of the local preglacia-

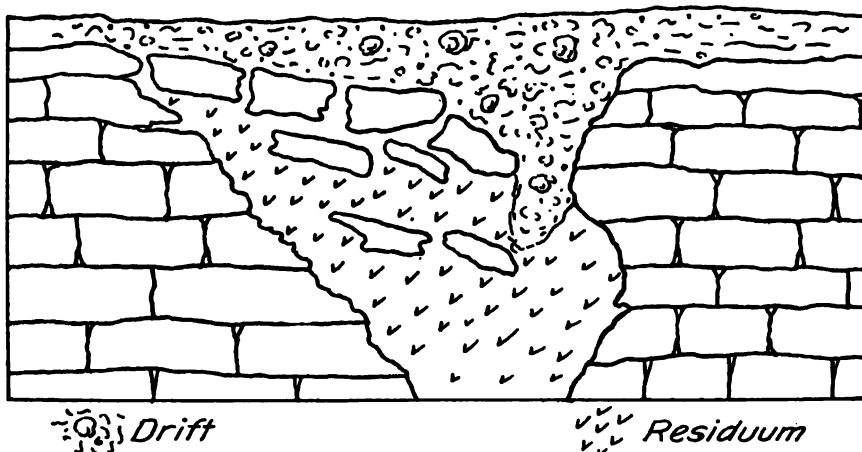


Fig. 6.—Tumbled rock due to preglacial weathering. Drift above, and residual chert and clay with no foreign pebbles below. About three and one-half miles west of Union Station, Columbus, and near Scioto River.

topography by ice erosion have been found in a number of the quarries, in the nature of residual clay and chert pockets in solution cavities at considerable depths; and in the multitude of sinkholes and underground water passages on the west side of the Scioto from Marble Cliff northward beyond Rathbone.

In a new quarry south of the highroad along the southern bluff of the Scioto some three and one-half miles west from the State House, the limestone is deeply weathered along joints with considerable residual clay and some chert in the joints and along bedding planes, but always without admixture of any glacial material. So far has the weathering advanced here that the layers have been let down and are a little tumbled and displaced. (Fig. 6.) Farther along the bluff westward and on the north side of the road are several other places where residual clay and chert without glacial fragments occur. At one place a vertical crack six to ten feet wide and twenty feet deep is filled with clay, chert and siliceous corals which have weathered out, but not a fragment of igneous material is intermixed. (Fig. 7.) At another point north of the road a quarry section shows many seams of residual clay and chert and some horizontal bodies in cavities closed by strong rock above, but open below, two to six feet high, and nearly or quite filled with chert and clay. These cavities would have been fair caves when empty.

In the new Casparis quarries west of the Scioto River the work has revealed the fact that the weathering has gone a long distance

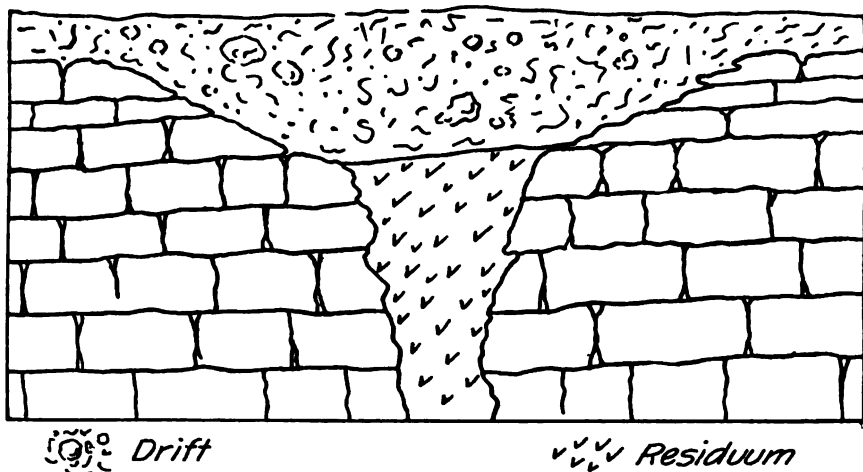


Fig. 7—Crevice in limestone containing residual chert, clay and silicified corals, but no drift. Till above. About three and one-half miles west of Columbus. Near Fig. 6.

below the present rock surface. Along joint planes, solution has removed soluble calcium carbonate and left the clay, an impurity in the limestone, on the walls, thus opening appreciable cracks. These have attained widths as great as two or two and one-half feet, ten or twelve yards below the surface. Along bedding planes further solution has occurred and openings have been made, into which are packed clay and chert from the decomposing limestone. Recently two teams with carts were kept busy some days hauling out this material from a group of pockets in the quarry. The lower pockets thus opened and filled by the work of ground water were at the very base of the excavation, which is fully fifty feet below the rock surface. Here is evidence of extensive and deep weathering. When it occurred cannot be established. Of course, it cannot be postglacial, when the surface of the rock

beneath a few feet of drift retains its striations perfectly. Further, if post-Wisconsin time has not sufficed to efface the striations on the exposed surface, and if, as has been estimated,¹ this period of time is as much as one-seventh to one-ninth as long as that from the Illinoian to the present, it does not seem possible that this deep weathering could have taken place in post-Illinoian time. The point may be made stronger by noting that the older drift seen in so many places is only weathered notably along its joint planes. Another possibility is that there was a still earlier ice invasion, so much earlier that this amount of rock weathering might have occurred since its date. But only two ages of drift have been recognized in Central Ohio. One would necessarily seem to be forced to the conclusion that this weathering preceded the oncoming of the ice. Still further weight may be added to this conclusion, when it is observed that all this deep-lying residual material is absolutely free from foreign pebbles, as it certainly could not be if it had been washed in since the ice had scattered foreign mantle all over the region. This applies whether the Illinoian or some much earlier invasion be the first.

Sinkholes.—From near Dublin, west of the Scioto and eight or nine miles north of Columbus, northward some ten miles may be found many sinkholes. They occur fairly close to the Scioto and also westward a mile or so from the river. They are openings into enlarged joints and cracks; often crevices large enough to admit a man can be entered from the bottom of the sink. Into many of them surface drainage is now poured and by them is led down and away to the river; but they are not to be correlated in formation with the present stream valley, for the cracks are as large leading away from the river as toward it. Such opened joints were found in one of the quarries northwest of Rathbone three miles west from the river, but no sink occurred above, because since the Glacial period, the drainage has not yet found its way through the opened joints and cracks to the river. Similarly enlarged joints were found on the east side of the river in several old quarries, but no sinks occur at the surface on that side except one on the rock terrace two miles above the storage dam where the drift had been removed by the stream. (p. 109). The opened cracks and joints seem to be a common feature of the limestones, but the sink at the surface only occurs where postglacial drainage has been successful in opening passages already existing, downward and away to some drainage line low enough to receive their waters. These passages, since so often not in use now, are certainly preglacial and were more or less obstructed by the glaciers.

Conclusion.—From the presence of the deep weathering found in the quarries, and of the enlarged cracks and joints in many places

¹ Chamberlin, T. C., and Salisbury, R. D., *Geology*, vol. 3, p. 414.

in the limestone, both of which are too extensive and too ancient to have been made since the Glacial period, it may well be inferred that glacial erosion was not deep enough to remove the partly weathered zone over this area. To what depth preglacial weathering had gone, we have no way of knowing, hence, of course, cannot fix the thickness of rock removed, but it is apparent that the glaciers certainly have not scoured off more than a few scores of feet of bed rock after removing the mantle. As was shown above, the Wisconsin sheet probably removed but little beside the mantle and frequently not all of that, while the earlier ice removed more than the last sheet, but only a little bed rock, and that in a manner so as to develop neither uneven nor valleyed topography.

Effects by Deposition.

Beside erosional effects, the glacier must have left its marks as a depositing agent, but this first advance and subsequent retreat could not have been very significant as a factor in present day topography, because the Wisconsin ice sheet over-rode and destroyed many of its features and then deposited new material over the ruins.

The deposition of drift by the earlier ice sheet would stop valleys and cause streams to take new courses and carve new valleys, thus providing the buried gorges which after being filled with later drift are unearthed or cut across by the present streams.

STREAM EROSION IN AN INTERGLACIAL STAGE.

Between the time of the disappearance of the earlier ice sheet and the approach of the later one, streams were busy developing valleys, draining basins, and withal getting possession of the land. These new valleys would not necessarily bear any genetic relation to those existing before the ice came on. They may have coincided with their predecessors in places and crossed them in other places. There should have been a very considerable development of tributary valleys as well. We know but very little of these interglacial valleys.

Buried valleys containing Wisconsin drift have been found in many places. The valley leading westward from Lewis Center to the Olentangy, has a wide section a little over half a mile west of the road and the Columbus, Delaware and Marion electric, and here no rock is found in the valley walls, except at the very bottom. The slopes are all of drift, while both down and upstream from the place, black shale occurs in both bluffs. A half mile south of this run is another in which the rock is entirely wanting for a quarter mile, and only Wisconsin drift occurs in the walls. It looks as if a pre-Wisconsin valley was here crossed by two present valleys.

Glenmary Run at the park crosses a similar drift-filled valley. The second run south of Africa on the west side of Alum Creek has a rock gorge at the mouth and upstream for a hundred yards, then the rock ends against Wisconsin drift in a steep contact. A quarter mile farther upstream the shale appears in the bed of the stream for fifty feet, then disappears again and is no more found in the run. The next run northward has no rock at all. Three and one-half miles farther north in the last big run south of Cheshire and west of Alum Creek, the stream is in a rock gorge for a half mile up from its mouth, then the valley widens out, the rock disappears and

only recent drift shows in the walls the rest of the length of the run. A dozen other occurrences such as these are known in the area under discussion, and they seem to admit of no other interpretation than that they indicate buried interglacial valleys. They are pre-Wisconsin because they contain Wisconsin drift. If made prior to the deposition of the Illinoian sheet of drift, they have been cleared of all drift of the older age at the points crossed by the present streams, before the later ice sheet came—a supposition which seems quite improbable.

Plant Occupation and Soil Formation.

While the streams were carving valleys, the plants and animals forced to evacuate before the advancing ice were able to return and again occupy the territory. Probably vegetation as a whole very promptly followed the ice as the latter receded, but not with the same relative mingling of species as occurred later. The ultimate grouping and distribution at any given time is the result of conflicts and adjustments to changing conditions. As the plants took possession, their partially decayed remains from year to year added carbonaceous matter to the surface portion of the drift, thus making a soil. In depressions where water stood, water-plants grew and their remains accumulated in the pond or swamp and brought forth peaty conditions.

Whatever of soil and peat was produced during the interglacial stage would be present when the returning ice arrived in the Wisconsin stage. Most of it no doubt would be dragged or shoved along by the ice or covered up with new drift. Parts of the soil and one peat bed have been found preserved between the two sheets of drift. In the east branch of Glenmary Run, north side and about one-fourth mile up from the junction of branches, may be found a yellow stratified clay along the stream bed; above the clay is a mass of characteristic old drift covered with a weathered zone and dark soil, and above the old soil lies Wisconsin drift.

Springwater Run enters Big Darby at the southern edge of Harrisburg. A short distance up this run on the north side, the following drift section from the water up, was recorded:

	Feet.
5. Yellow, loose, unweathered till.....	30 +
4. Light gray layer, like Southern Illinois soils	1
3. Fine, weathered sand and sandy till	3
2. Coarse, weathered, gravel having smooth contact with No. 3 above	1
1. Old characteristically jointed, blue drift.....	5-6

A mile farther up the same creek occurs 20 feet of blue drift, capped by 10 feet of a much weathered dark variety, which is overlain with several feet of fresh drift. About two and one-half miles west of Matville at the turn north of the road, in the little stream which crosses the highway, the following section was noted:

Old characteristic, indurated boulder clay for three feet above the water, then about a foot of badly weathered dark soil-like material covered with

six to eight feet of fresh gravel with unweathered drift to top of section. A steep till cut occurs about one-half mile north of Morgan station at the east bluff of Big Darby, exposing the following section:

	Feet.
4. Weathered till and present dark soil grading down into the next (No. 3).....	3-4
3. Fresh, loose, stony yellow clay till with sharp contact between it and No. 2	12-15
2. Much weathered, dark compact soil-like material gradually passing into the next below (No. 1).	2-4
1. Characteristic dense, blue old drift from water up.	50

Across the Scioto from the Hartman farm the little stream which heads near Grove City is digging out old peat. At least four feet of this material is exposed, half below the water and half above. Fresh drift constitutes the bluffs on both sides here. Apparently the stream has cut into an interglacial peat bog.

All this erosion, soil formation and development of peat require time and hence give us a suggestion of the duration of the interglacial period. Evidence derived by examining valleys¹ on Illinoian drift which has not been covered by later ice sheets, points to a period from the beginning of the interglacial stage to the present some seven to nine times as long as that since the Wisconsin ice melted out. This conclusion is based on the relative maturity of valleys and completeness of the drainage system in Illinoian drift as compared with the same in Wisconsin drift, together with the amount of weathering the two sheets have undergone and several other factors.

THE SECOND ADVANCE OF THE GLACIER.

The second advance of the ice from the north was probably similar to the first. But instead of finding the topography in advanced maturity as in the first instance, the second ice sheet must have found a till plain with moraines rising above it and multitudes of youthful valleys carved in both plain and moraines. The landscape must have been something like the present except that the valleys were larger, longer and more mature; the tributaries more numerous, longer and more branched; and the interstream remnants of the till plain less extensive, narrower, more serrate at their margins, and more completely possessed by the streams. The drift of the first invasion may have been similar during the interglacial stage, in composition and structure to the present surface deposits; but the second sheet of ice rubbing over and pressing upon the older drift probably compressed, packed, and in places, jointed it,² and thus left it in the dense compact condition so often seen, which aids in recognizing it today. Illustrations of the power of the ice to shove and distort over-ridden material are not wanting.

¹ Chamberlin, T. C., and Salisbury, R. D., *Geology*, vol. 3, p. 414.

² Carney, F., *Metamorphism of Glacial Deposits*, *Jour. Geol.*, vol. 17, 1909, pp. 473-487.

Illustrations of Ice Shove.

When the excavation for the Ohio State University Student Building was made, sand and fine gravel layers complexly crumpled were exposed below a boulder layer, recent drift, and the present soil. The boulders were much weathered, some to complete crumbling, but the drift above was fresh. The crumpled sand layers were in the older drift over-ridden by the later ice.

In a little run east of Big Walnut and leading into that stream a mile above Galena, is an outcrop of shale which is much disturbed and folded. Drift pebbles have been crowded into the shale and all much crumpled but not removed. In several places short folds and crumplings have been seen in the Ohio shale. One fine instance may be noted west of Alum Creek some three miles above Westerville; another in the clay pits opened for sewer pipe materials at North Columbus.

Possibly Several Ice Invasions.

Whether the ice entered the Columbus region more than twice is not known. That may be the case, for in other regions in similar latitude certainly more than two invasions have been recorded. If the advances number more than two, the little known ones probably antedate those better known. Whether or not there have been more than two advances of the ice is also of little significance in this region, in as much as two later known advances have both gone entirely beyond the area. Perhaps the greatest moment of the question attaches to what may have been done in the interglacial stages. It has been seen that erosion in an interval between two advances of ice gives immature valleys partly in drift and partly in rock. We must have a few youthful preglacial valleys developed as the ice came on, interglacial youthful valleys for each interglacial stage, and one set of postglacial valleys. If only an Illinoian and a Wisconsin invasion occurred, our postglacial streams would encounter two sets of buried valleys; and as the number of invasions increases, the number of sets of valleys thus encountered must also multiply. The wonder is not that we find sections of so many buried valleys, but that we do not find more¹. As was suggested in connection with the discussion of valleys containing Illinoian drift, the fact of the preservation of so many pre-Wisconsin valleys although subsequently traversed by the Wisconsin ice sheet, is a strong argument for moderate glacial erosion beneath the last Scioto lobe. The fact that we have more or less of two sets of youthful valleys buried beneath our drift, and possibly remnants of still other systems, complicates greatly the problem of mapping any one system. One cannot always be sure to which erosion period any given buried valley may belong.

The work of the ice sheet last to deploy over this region was no doubt similar to that sketched for an earlier one; but its depositional or constructive work has been very much more perfectly preserved; primarily, because no subsequent leveler has appeared to obliterate the work, secondly because the time since the work was done has been too short for the subaerial processes of destruction to more than begin their work.

¹ At least thirty-two distinct valleys filled with drift, and now crossed by the present streams, were found. Some are very small, 50 to 100 feet across, others seem to be over a mile wide.

CHAPTER IV.

PHYSIOGRAPHIC HISTORY.

THE WORK OF THE LAST OR WISCONSIN ICE SHEET.

Reference to the map of the Scioto glacial lobe (Pl. 14) makes it clear that the last ice sheet advanced with a broadly lobate margin. During its maximum stand its eastern margin extended from near Mansfield approximately southward to Lancaster; then the margin swung southwestward past Adelphi and Chillicothe, to near Hillsboro, whence it bore northwestward to Springfield, Cable and the hills east of Bellefontaine. The lobe at this time covered from 4,000 to 4,500 square miles. Columbus and the Columbus quadrangle are pretty well centered in this great area.

Lake Deposits.

The effects of ponding back the streams, forcing them over divides, and overcharging them with waste, as outlined under the Early Continental Glacier, were apparently repeated in the advance of this last sheet. As instances of the ponding effects reference may be made to two deposits which possibly belong to the same body of water although the exposures are some fifty feet apart vertically. They occur north and northeast of Reynoldsburg.

A little over one and one-fourth miles straight north from Reynoldsburg, on the east bluff of the run leading southwest, there was found a splendid section of sands and clays, with a height of over 20 feet. The beds are horizontally stratified and consist of clays and very fine sands, but apparently without organic remains. Two sand layers carry very perfect ripple markings five inches from crest to crest and one inch high, very similar to those revealed in the Berea sandstone, and along the margins of the bed of Lake Erie today. These ripple markings of such large size seem to argue for a considerable body of static water. Just about a mile southeast of Blacklick station and where the north and south road crosses the run, appears another similar deposit of fine sand and bluish clay horizontally bedded. Plant remains badly decayed are abundant, but no ripple marks are visible.

Outwash.

As an example of aggradation during the advance of the ice, the phenomena at the private suspension bridge over Rocky Fork may be cited.

About one and one-half miles east of Gahanna the old drift in a pre-Illinoian valley mentioned on page 60. has been partly cut out, as if the stream returned to its earlier valley when the Illinoian ice melted back; then after the removal of much of the drift, stratified gravel and sand (seen in part at the top of Pl. 16A), have been laid in the strath apparently as outwash prior to the deposition of Wisconsin drift, for there is a thickness of 25 feet of the latter over the stratified material.

Compacting Old Drift.

The Wisconsin ice is probably in part responsible for the compact and jointed condition of the old drift;¹ for, with its thickness of hundreds, not to say thousands of feet and its sliding motion it must have tramped, and possibly jointed loose material over which it crept.

Carving Rock Surfaces.

It is also probably the agent which made many of the striations on rock surfaces. While the earlier ice must have made polished, striated and grooved surfaces, this last sheet, wherever it removed all old drift, would leave its markings across the older ones or first remove them and then carve its own record.

WITHDRAWAL OF LAST ICE SHEET.

Having attained its maximum dimensions and having stood there for a time sufficient to free by its melting, and deposit around its margin a well marked terminal moraine, it began its last stage, namely, its melting and the laying of the till sheet and interspersed recessional moraines, with their associated fluvio-glacial phenomena.

The location of the margin of an ice sheet is determined by the relative rate of forward movement and of melting. When ice movement is more rapid than is necessary to compensate for the loss in volume by melting, then the margin or ice front advances; but when the movement is nil, or too slow to balance the waste by melting, then the ice front retreats. The rate of melting and rate of movement are both variable, hence the ice front is oscillatory, advancing, halting, retreating and halting at various intervals, sometimes halting briefly, sometimes for a long time, sometimes retreating intermittently, sometimes advancing in a similar manner. Occasionally considerable areas of ice melt, when there is practically no compensating forward movement.

The Marcy Moraine.

With several halts occupied by moraine building, and several retreats which left a more or less featureless inter-morainal till plain the glacier ultimately withdrew from its maximum stand to the southern margin of the quadrangle. The first land within this area to be freed from its burden of ice was about two square miles in the southeastern part, that lying beyond the little Marcy moraine. Reference to the general map (Pl. 14), shows this moraine to be probably the innermost or last of the moraines grouped by Leverett² under the heading "western member of the eastern limb" of the Scioto lobe system. It is hummocked and kettled but usually the depressions have been drained artificially. A small tile factory uses the clay, which has accumulated by surface

¹ Carney, F., Jour. Geol., vol. 17, 1909, pp. 481-484.

² Leverett, F., Mon. U. S. Geol. Survey, No. 41, pp. 383, 405 f.

PLATE XVI.



A.—Buried talus in bluff of Rocky Fork valley near suspension bridge, one and one-half miles east of Gahanna. Bed rock horizontally stratified from center to right. Drift with boulders below, and some stratification above on the left. Ancient talus of shale alone forms a wedge between drift and bed rock, and rises from water almost to top of bed rock.



B.—Hayden Falls. About ten miles northwest of Columbus. A more resistant limestone layer at the crest of the fall.
(Photo by Dr. C. R. Stauffer.)

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wash in one of the kettles. A few are drained naturally. Outside the kettles the drift is stony. There are many rounded and angular pieces of sandstone from the hills to the north and many fragments of other stones from Ohio and Canada mixed with the clay and sand of the moraine.

This moraine lies nearly three hundred feet higher than the plain to the west and north. To make it the ice rose over the mature slopes of the resistant sandstone between Canal Winchester and Lithopolis. The presence of these rock hills so obstructed the ice that its front was here markedly held back, as may be seen by following the moraine westward and southward. It swings here quite abruptly southward as it leaves the quadrangle, because the lower land to the west allowed the ice to advance farther and more freely in that direction. The physiographic map (in pocket) shows details of the distribution of the moraine.

The Lithopolis Moraine.

After building the moraine just described, melting of the glacier came to exceed the forward movement and the ice disappeared from the hilly tract, scattering a till sheet over the mature rock slopes. Not enough waste was left here to completely conceal previous topography but sufficient to fill many valleys, and, with the little erosion accomplished, to even and round the forms of the hills and leave a good light, long-lived soil basis.

The streams in carving their present valleys have often encountered the rock, but they also reveal several very thick bodies of drift where former valleys must have existed. It seems impossible to so correlate the buried valleys as to discover any system. The map (Pl. 15) shows in dotted lines where some of these valleys are believed to be.

After the ice had melted entirely off of the hills, it seems to have pushed forward a little, shoving the drift in masses against the hillsides both east and west of Lithopolis, just as has been observed in the Alps and in Alaska. Around the village the moraine seems to be wanting. In the area east of town, there are two crests to the moraine less than a fourth mile apart but practically parallel. Each ridge is now discontinuous, and probably was always so, though erosion has done much to isolate the sections. Three deep drift-walled gorges cut through both ice-front moraines to a depth of 60 to 80 feet, but the rock is not reached in any of them.

A Marginal Lake.

Just west of these moraine ridges, the rock rises almost as high as the moraine, and the drift is so thin that the little stream has cut down through it to rock. At right angles to the east end of the moraines lies Chestnut Ridge of solid sandstone rising one hundred to one hundred

and fifty feet above the morainic ridges. From the south end of this ridge, high rock topography connects across westward with the hills upon which Lithopolis stands. Thus, before the ice came there was a broad valley opening north, and bounded on three sides by rock hills. When the ice deposited drift in the north side opening, local water was ponded and a small lake, marginal to the ice, was formed. Clays and sands were laid on its floor but no streams other than hillside rills and surface wash seem to have fed it, hence no deltas remain and the shoreline phenomena are very weak. They consist simply of a sandy zone about the same height, only preserved in places. The topography and the clays, now badly dissected, are the best evidence of the existence of this little marginal lake. That it was short-lived is shown by the absence of outlet as well as by shoreline feebleness. That the moraines are due in part to pushing is believed, both because of the shortness of the lake history, and because of the failure of the moraine, beyond where it could be pushed up against the rock hills. The difficulty, however, of identifying pushed moraine is recognized. Beginning a mile west of town the moraine leads away southwestward, flanking the hills nearly four miles, first as a weak terrace, then as a ridge, until it smooths out into the level till plain and entirely disappears without reaching the edge of the quadrangle.

Phenomena due to Melting of Stagnant Ice.

After the time occupied in building the moraine which helped retain the lake, a short period if much of the deposit was pushed up, the ice-sheet seems to have passed through a period of dissipation with essentially no movement forward. This melting would probably permit the waters of the lake to escape. The areas of rather characteristic morainic topography around Waterloo, possessing kettles and sags and swells, together with those across Little Walnut to the south and those south of Groveport for two or three miles, seem to defy systematization. They may be classed as ablation moraines,¹ left by the melting of stationary or stagnant ice, and consisting largely of drift distributed unevenly in and on the ice, freed and let down to the ground as the ice vanished. Another area probably of the same origin, but possibly to be correlated with the moraine mentioned on either side of Lithopolis, occurs farther northward just east of Oakland.

Starting about a mile southwest of Winchester a circuitous, crooked ridge or row of hills of sand and gravel leads irregularly westward a mile where it is crossed by Little Walnut. From there it can be traced southward, then southeastward, bifurcating at the end and terminating,

¹ Tarr, R. S., Folio U. S. Geol. Survey, No. 169, p. 124 (Field Edition), describes this phenomenon, which must have been common in many places as the ice-sheet was disappearing. Also, Zeitsch. für Gletscherkunde, III Band, 1908, pp. 85f.

after over three miles of crooks, less than a mile and a half from the starting point. The whole feature is known locally as the Irish hills. It consists of good clean gravel and sand stratified obliquely down slopes, and crossbedded, but it is always covered with one to ten feet of unstratified drift. Where it is intersected by the stream the 30 to 35 feet of gravel rests on blue, hard till exposed ten feet above the water. Its structure indicates that it was made by running water over-charged with waste and flowing in confines now removed. The waste on top further testifies to an origin underneath ice, which, as it melted mantled the gravel with till. Furthermore, it must have been formed when the ice had ceased to move forward, else the restraining walls of ice would have brushed it and confused its stratification; and when the ice had become thin, else the weight of the ice would have closed any open spaces or tunnels through it. From the position of pebbles in the ridge, and the position of the ridge with reference to the moraine, it is believed that the water flowed toward the divided end. Such a deposit is classed as an esker. Other minor gravel ridges of this same sort occur two and three miles respectively east of Brice and south of the elbow in Blacklick Creek.

The head end of the Pickerington¹ esker now bearing the Pickerington school building, also belongs to this same class of features and dates from the same time. The esker drainage must have been eastward, while the present drainage is westward. About a mile west of Duvall are some sand ridges, esker-like but not conspicuous, which are the beginnings of the large esker extending from this point southward nearly to Circleville.²

In this vicinity the Scioto Valley gives off a branch on the eastern side which continues some miles southward and then rejoins the main valley. The river must have been a divided stream here immediately subsequent to the melting out of the ice. The floor of the side valley, now entirely abandoned, lies about twenty feet below the till plain, and about thirty feet above the present river. It must then have been abandoned for a long time, probably more than half of postglacial time. A minor stream enters it from the till plain to the east and flows northward to the river. The Ohio Canal from Lockbourne southward occupies a part of the abandoned channel.

West of the Scioto in this latitude is an old channel now occupied by a minor stream entirely too small to have made it. This, too, is a remnant of early post-glacial drainage before the adjustments were as perfect as today. At the same time the precursor of the Big Darby was a divided stream, and one part has left an abandoned channel some three miles long lying west of the Darby and south of Harrisburg. The history of this channel has been carefully studied and its origin explained.³

Two and one-half to three miles due north of Canal Winchester, is a group of gravelly hills of rather weak relief resting partly on the sandstone and partly on drift. In places the gravel is well assorted but in other parts

¹ Leverett, F., Mon. U. S. Geol. Survey, No. 41, pp. 428-429.

² Idem, pp. 429-431.

³ Nichols, R. H., Ohio Naturalist, vol. 11 (1910-11), pp. 210-213.

it is not. Two large kettles in the group contain water, and in the northern part of the area was once a lake of two or three hundred acres. It is now drained and furnishes fine rich soil, as such places usually do. About a mile north of Winchester is another minor lake bed as is shown by its black, humic soil and sandy margin.

A small hill two miles west of Lithopolis, which may easily be mistaken for a morainal form, is an outlier of Bedford shale on the Ohio shale.

Shadeville-New Albany Moraine.

Another minor halt of the ice-front is marked by a series of patches of moraine topography, not a continuous band, entering the quadrangle from the northeast at a point about three miles east of Center Village, developing into a fine strip of moraine southeast of the village, and extending as such southward and southwestward past New Albany and Ovid. Here it becomes more patchy but can be traced southward past Taylors to Brice,¹ then southwestward to a well-defined ridge somewhat uneven-topped and containing two or three excellent kettles about two miles northwest of Groveport. This ridge portion is crossed both by the Hocking Valley railroad near Big Walnut Creek and by the Groveport pike and Scioto Valley Traction line. From the latter the kettles may be discerned as cattail swamps or ponds north of the road. The other branch of the Scioto Valley electric crosses the moraine a mile north of Lockbourne. While the contour lines with the 20-foot interval do not lie so as to show any particular difference in the altitude on opposite sides of this part of the moraine, the four locks in the canal offer positive testimony to the difference, which can also be seen by the student at proper points. Farther northeast along this moraine a reverse difference in altitude on opposite sides appears, because the deposit was laid on a rising rock slope. The ice lay on initially lower ground than that upon which the moraine was placed, and that outside the moraine was still higher. On account of this relation the moraine appears in some places as a terrace on the hillside, with lower land on the ice side than on the other.

Southwest of Lockbourne and across the Scioto are a group of swells with several kettles, some still swampy; and westward from them around Commercial Point, may be found a considerable number of little knolls. At Matville and vicinity are others, and westward from Harrisburg as far as the Franklin-Madison county line are many more. From Lockbourne on, one would hardly be justified in calling the isolated hummocks and knolls moraine, if it were not for the well developed moraines farther east and northeast with which these features seem to connect. The crookedness of Springwater Creek, the lack of symmetry in its valley and the abundance of springs along its course are suggestive of moraine modified by the stream, which probably owes its position largely to these morainic accumulations.

¹ Leverett, F., Mon. U. S. Geol. Survey, No. 41, p. 427. This is the moraine, a part of which Leverett describes as occurring seven miles east of Columbus.

Associated Phenomena.—Associated with this moraine are several features of importance which date from the same time as that of the moraine. First, the moraine terrace, explained in the previous paragraph, occurs in the southeastern corner of Delaware County and again a mile east of New Albany, where it holds Blacklick Creek to a southward course, although the initial postglacial slope descends faster westward. From two and one-half to three miles straight east of Gahanna in this morainic belt are two north and south drainage lines not now occupied by streams. The eastern one about a half mile long is at the foot of a steep, west-facing slope and probably represents the work of marginal drainage, water flowing along the ice-front and restrained on one side by ice, on the other by the rock. When the ice was gone it left a one-sided channel. The western channel is a little lower, was used after the completion of the former when the ice had melted back a little, and was probably only in use a short time. Gravels deposited south of these channels were in part dragged through them.

At Lockbourne the moraine is fringed on the south side by an inconspicuous outwash plain, or better, by a frontal apron, because it is not confined in a valley but spread thinly. It consists of gravel and sand, coarser near the moraine, and extends two or three miles southward. This deposit has recently been extensively cut into for grading materials by the Norfolk and Western Railway company, thus revealing its nature.

The halt for the construction of this moraine must have been a short one, and much shorter in the southern than in the eastern parts. Not only does the size of the moraine sustain this point but the relative distance between the moraines in the southern and the eastern parts supports the same conclusion. The withdrawal of the ice between the making of the Lithopolis moraine and that of the Shadeville-New Albany moraine was much more extensive around the southern border than along the eastern edge; hence, the duration of the halt may consistently have been less here at the south, resulting in the smaller moraine. The crookedness of the moraine suggests that the ice margin was quite ragged during its building. The unequal development of the moraine may be the result of varied distribution of drift in the ice, which might well result in differential melting and thus account for the ragged margin of the ice.

Features Between the Shadeville-New Albany and the Lithopolis Moraines.

While the ice-front was withdrawing from the earlier to the later of these moraines, the history chronicled in the former similar period of ice melting was repeated with variations.

The Hibernia Esker.—This ridge distinct for more than a mile each side of the National pike and Ohio Electric railway at Hibernia, eight and one-fourth miles east of High street in Columbus, is a rather prominent feature. Where the highway crosses the ridge, about a mile south of Hibernia, it is thirty feet high above the till plain,¹ and the well here did not reach rock at a depth of 70 feet. To the south the ridge divides and terminates without a sand plain. Northward, it decreases in height and flattens out. The stream crossing it, evidently found it low and now has cut it entirely away at the crossing. A large gravel and sand pit is opened in the esker at Hibernia. Beyond this point northward the ridge is strong for a half mile, then less marked for nearly a mile. The road follows it closely. Here it entirely disappears except for a short section of low ridge a mile west of Taylors and south of the Pennsylvania-Baltimore & Ohio railroad. It is made consistently of gravel throughout and capped with a mantle of till.²

Gahanna Esker.—Northward about two miles farther is found the southern member of a group of related features consisting of kames, esker and sand-plain which beautifully illustrates their interrelations. Each feature is small and somewhat mutilated by erosion but readily identified. The sand-plain or esker-delta is at the southern end. At the other end west of Big Walnut at Pinhook is the kame area. From the latter southward mostly on the east side of the stream are scattered the fragments of the esker, opened in several places for gravel. The ridge fails about a mile north of Gahanna and the sand and gravel-plain begins. Broken by erosion at Gahanna, the sand-plain continues south and west of town for a mile and a half on the opposite side of the stream. This complete group of kame, esker and sand-plain seems to be in no way connected with the Hibernia esker, but was formed later as the stagnant ice melted.

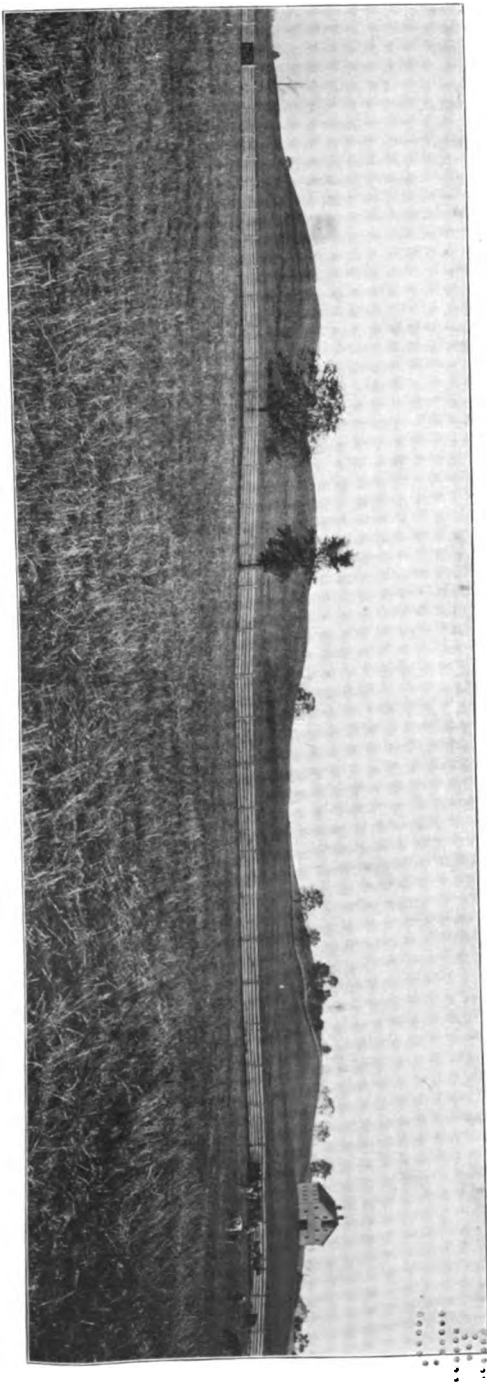
Galloway Esker.—Beginning more than a mile from Galloway up Hellbranch Run, small ridges of gravel occur. The series continues intermittently down stream for nearly four miles. The stream and road-makers have removed considerable portions, but enough remains to mark the series as an esker, made during this same period of ice recession. South of Galloway occur three or four lake beds aggregating over 100 acres of rich black soil. They occupy as many large shallow kettles in the drift. Stream work, aided by artificial means, has completely drained them all.

Abandoned Channels.—Two and one-half miles east of Pinhook, an abandoned channel twenty feet deep leaves Rocky Fork valley on

¹ Leverett, F., Mon. U. S. Geol. Survey, No. 41, pp. 430-431.

² Several recent openings in this ridge reveal its true water-laid nature. The boulders occurring upon it are undoubtedly a part of the unstratified drift cap.

PLATE XVII.



Kames of Spangler Hill, four miles south of Columbus. Looking south.

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the west side and continues southward parallel to the latter for about one and one-half miles, then again joins Rocky Fork. Probably the precursor of the present stream was, during the melting of the ice, a divided stream and here as elsewhere, the ice-drainage waters were eroding instead of depositing.

Kames, Baker Hill.—Two miles or more south of the Driving Park, Columbus, and near the Scioto Valley Traction line is a peculiarly stratified, rounded, gravel and sand hill rising fully 50 feet above the level till plain. It may probably best be called a kame, although a considerable portion of the stratification is entirely too steep, contorted, and tumbled for purely deposition work. No kettles are found on its surface, but rather the whole form is smooth and rounded remarkably like a low drumlin. The mass must have been laid with some ice underneath and then let down by melting to give such a tumbled structure as is constantly presented in the cuts made by removing sand and gravel. A thin sheet of unstratified drift mantles the lower slopes, but there seems to be none at all over the top, indicating that no waste-burdened ice existed over the place when deposition ceased. This hill has proved of so much economic importance, because of its contents, that the Norfolk & Western Railroad company has constructed a stub track to the hill preparatory to its complete removal.

Kames, Spangler Hill.—Four to five miles south of South Columbus are the finest kames to be found in the area. They are situated two to three miles north of where the margin of the ice stood when the Shadeville-New Albany moraine was built and cover a little less than one square mile. (Pl. 17 and Pl. 18 A.) They consist of some twenty or more gravel hills ranging in height from a few feet up to sixty or seventy, above the surrounding till plain. Obliquely stratified sand and gravel are exposed in several places where openings have been made. Huge kettles, empty with one exception, are enclosed between the knobs. In the eastern part is a kettle lake-bed now thoroughly drained, floored with fine black soil and under onion culture. (Pl. 18 B.) The former shorelines, with a small sand bar on the southwest side of the area, can be traced much of the distance around, and they, with the lake-bed deposits and the smoothness and levelness of the lake plain testify to the presence and extent of the now extinct lake. The deposits are not thick and probably came largely from the moraines on the east. The lake covered at least twenty acres at its maximum, and must have been filled nearly full of clay and organic matter for the shoreline features rise but very little above the lake bottom. Around the kame area and connecting with the Scioto Valley at the north end and with the Big Walnut at the south, extends a broad, shallow, abandoned channel through which water flowed at some time during the melting of the ice.

A considerable supply of drainage would be required to build so large a group of kames as this. The arrangement of hills, lake-bed, channel and moraine indicates that at the cessation of forward movement and the completion of the moraine above mentioned there was here a notch or re-entrant angle two miles deep in the margin of the ice. Into this notch drift, making moraine, was piled, and now gravel, a little farther north, making kames. As shown on the physiographic map, some of the gravel accumulated in the kame hills while other parts were carried southward and laid along the Scioto as outwash. Much of the latter has been eroded.

Moraine for a mile south of the kames should be correlated with that described under the heading Shadeville-New Albany moraine.

Tumuli—In Harlem Township, on the New Albany strip, and around the village of New Albany, are a number of low rounded to ovoid drift hills or tumuli. They range in height from ten to twenty-five feet, in length from an eighth to one-half mile, and in width from an eighth or even less to rather more than a fourth mile. Stony till is almost the universal content of each, but a few were found containing some stratified gravel and sand. One mound two and one-half miles east of Westerville and one-third mile south of the county line near the highway, contains no gravel and very little drift, but seems to be of shale. This is the only one known to contain bed rock. Many are known to contain no rock. They seem to be essentially drift features and similar if not identical with other knolls in the moraine last mentioned.¹

Outwash.—Gravel along the Scioto Valley, recent and fresh, but covered sometimes with a few feet of till is abundant. The map shows only the surface exposures and much of this may be of later date. For a mile or more east of that shown on the map between South Columbus and Shadeville, the gravel occurs and is reached below the till by many wells. At the starch factory in South Columbus flowing wells have been made ending in this gravel at depths of fifty feet and more. A half mile farther east, a large gravel pit has been opened in it. Wells between here and Baker Hill reveal the gravel only at depths of fifty feet or thereabouts. The thick till cover both here and southward along the river shows the gravel to have been laid under the ice and covered a little in the final melting, or to belong either to the advancing ice or to an earlier invasion. In some places it seems to have been but very little covered. Near the river, part of the cover may have been removed. The later deposits are discussed on page 97.

The Till Plain.—Southwestward from Columbus the topography is exceedingly level and is locally known as "the plains." The apparent uniformity is largely in form, for even the surface material varies considerably. In the spring when the ground has been prepared for planting and before the crop has grown to cover it, the land is seen to be spotted,

¹ Many of these features were mentioned by Leverett, *Mon. U. S. Geol. Survey*, No. 41, pp. 426-27. Better opportunities for study have been given the present writer, and correlations can now be made which were not possible when the former work was done.

PLATE XVIII.



A.—Kames of Spangler Hill looking southwest. The kames stretch away about a mile. On the left, over the fence, is the lake bed.



B.—Looking east of Spangler Hill. Moraine east of lake bed in the distance. Looking southeast.



dark to black blotches in a gray or yellowish background. The darker areas are usually very slightly lower, and can sometimes be located even when the crop is grown, by the size and vigor of the latter or by its darker green color. The darkness of color in the soils of these patches is due to organic matter. It seems probable that when first made, the till plain may have been a little less level than now, and that the depressed areas, once more or less swampy, have been aggraded by surface wash of clays and by the admixture of partially decayed vegetable remains. Thus, there has been made from a very slightly undulating till plain a still more level feature. It has been thought that much of this level country was once occupied by a glacial lake,¹ but there is no stratification to be found in the surface materials, except in a few of the larger and presumably once deeper black earth depressions. The part played by surface wash in augmenting the levelness is undoubtedly small.

South of Columbus and east of the Scioto, the plain is often equally level though in smaller tracts, because the streams have cut little valleys across it. This region has long been known as the "barns," a corruption probably of the "barrens" in deference to its former relative unproductiveness as compared with surrounding tracts.

The Westerville Moraine.

After this period of excessive melting with the forward movement at a minimum or nil, a slight change in conditions began and the balance of melting and advance was again established. The margin of the ice during this minor halt is marked by the Westerville moraine which enters the area somewhat scattered in the northeast corner, leads westward four to five miles, then southwestward as a series of isolated hummocks to a point two and one-half miles south of Galena and west of of Big Walnut Creek.

Here unmistakable moraine begins in a hundred-acre patch of hills somewhat modified by erosion and cut entirely in two by a little run. Nearly southward from this area the moraine continues as a narrow, rolling belt to the Delaware-Franklin County line, then widens into a broader, bumpy, kettled strip nearly to Blendon. It probably never was well marked as moraine beyond this place, either because locally, the retreat was too rapid, or because the ice was too free from debris. Several phenomena however, indicate the position of the ice border southward to a kettled rolling area a mile southeast of Linden, and then southwestward to gently rolling moraine topography between Alton and Galloway.

Further evidence upon which the ice-front may be traced follows. Very thick drift at Minerva Park and southward to Linden with con-

¹ Orton, Edward, Geol. Survey Ohio, vol. 3, p. 646.

² Bownocker, J. A., a fact and explanation contributed orally.

siderable work of minor streams in it, sufficient to destroy true moraine forms, marks the course. Beginning at Park's Mills east of the creek and leading almost a mile and a half north is a marginal drainage channel with the rock east of it and gravel and drift to the west; and five hundred yards east of the northern or upper end of this channel is another short one behind a small hill, cut in shale but not used today at all. These abandoned channels were carved by marginal waters during the minor halt of the ice, while the ice-front was crowded a little against a rising shale slope. Fair moraine topography with two or three swampy kettles toward the south occurs one to two miles southeast of Linden. These swampy tracts have been scraped out and walled in a little to make a series of artificial ponds for duck raising and ice cutting. Through the city nothing remains to mark the ice border, but west of Greenlawn cemetery is a group of morainic hummocks and north of them several more. Along Scioto Big Run from the point where it is crossed by the Baltimore & Ohio Southwestern railroad, between Briggsdale and Urbancrest, to the Big Four crossing of the same stream three miles farther up, the topography is very irregular. Hummocks of drift are common in positions where the stream could not have made them, and sections of the valley mark places where kettles once were, having now been cut through by the stream. This creek nowhere touches rock but has cut deeply into drift. It seems probable that if no stream had modified the topography where the creek flows, one would with assurance and propriety map moraine. Westward from the Big Four crossing above mentioned, numerous low hummocks and minor swells with occasional kettles, now drained, mark the margin of the ice during this halt and permit it to be traced to the Big Darby. Off the quadrangle westward one-half to one mile along the National Pike and south from it, thickened drift, gravelly hummocks and black-soiled sags mark the same line. The curve traced by this series of features is quite similar to that of the Powell moraine yet to be discussed.

The Till Plain and Associated Features.—Northward from the western half of this moraine for a dozen miles, including the Hilliards, Powell and Worthington interstream areas, practically as far as the Delaware-Franklin County line, the till plain is remarkably level and featureless save for the post-glacial erosion to be described subsequently. The Toledo & Ohio Central railroad passing over this plain, through Amlin and Kileville covers 25 miles without a turn, a grade or a cut except where it crosses a couple of little runs and the Powell moraine.

Just south of the road a mile north of Marble Cliff is found a little group of kettles in the till plain. One of these has become a peat-bog, and if one may judge from the black, humic condition of the soils, others certainly were somewhat peaty when drained. In fact, many areas on the Hilliards and Powell strips south of the Powell moraine must have been swampy if not even slightly peaty at a prehistoric date. The plain is as spotted with

dark and light soils as is that farther south. Corroborative evidence is recorded on the Soil map.¹

Drainage lines established and used during the melting of the ice in its stagnant condition following the making of the Westerville moraine, are now marked by several interesting features. The Columbus esker fully described by Morse² is a little ridge (Fig. 8) with its accompanying sand plain to the south lying about half a mile east of the Ohio State University campus. It has been nearly obliterated by street and building excavations and grading.

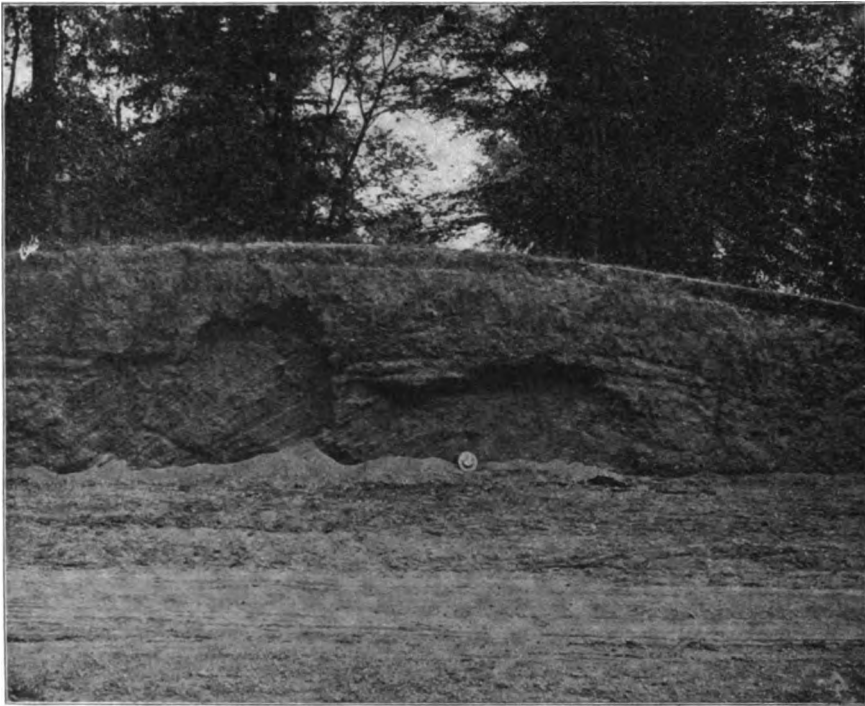


Fig. 8—Columbus esker. Structure revealed at 16th Avenue between Summit Street and Indianola Avenue. Looking south.

So far it has been impossible to trace any connections farther than mapped. If the southern part of this feature marks the edge of the ice during the Westerville moraine building (which seems improbable), the ice margin must have been very crooked here. It is more likely that the esker and sand-plain were made wholly under the ice, as both are covered with a sheet of till. Another drainage line lies west of the Olentangy and begins about opposite Clintonville. This is not an esker, but a channel, now separated from the Olentangy by a sandy or gravelly area sometimes in the form of a ridge. It may be traced from the starting point mentioned, southward a mile and a half to where it divides for half a mile, the parts reuniting near Lane Avenue; from whence the course can be traced to a point opposite the State University. Here it leads into the present Olentangy channel. A third drainage line is a channel, mostly in rock, west of the Scioto, over a mile in length, and extending from a point opposite the Columbus Fishing and Gun Club southward. These last two channels have no streams at present. They are interpreted

¹ Map 20, Columbus sheet. Bureau of Soils, Rept. of Field Operations, 1902; and Map 30, Westerville sheet, Bureau of Soils, Rept. Field Operations, 1905.

² Morse, W. C., Ohio Nat., vol. 7, Feb., 1907, pp. 63-72.

as water ways during the waning of the ice, but probably not long after, because the present river courses must have been better water ways, and hence would take care of post-glacial drainage. They certainly have been abandoned during the cutting of the present valleys below their levels.

Two and one-half miles northeast of Westerville a channel cuts obliquely across the moraine. Its length is about one-half mile, width a hundred feet, and depth ten or twelve feet. Its walls are quite distinct, although it has not been used for ages. It was undoubtedly made and used by water from the melting ice for a short time during its recession, but ever since has been isolated and wholly unconnected with any drainage system.

The Powell Moraine¹

One cannot with certainty discover how far the ice melted back during the period of recession just discussed, but beyond a question the minimum retreat was to the present Powell moraine. The rather bold south-facing front, the very considerable height of the moraine together with its uniformity in height, its lack of kettles, and the total absence of any ice front phenomena on its inner border indicate that the moraine is submarginal, i. e. that the nose of the ice lay upon the moraine during the accumulation of the latter. While the western half of the moraine in this area sustains the argument very well, the eastern part was probably less over-ridden. Since the moraine is rarely less than a mile in width, and often two miles wide, it seems probable also that the ice-front oscillated during the building, moving forward more rapidly than it melted, then melting back a short distance, only to advance again over the moraine. The compactness of the drift about Powell, New California and other points as reported by well drillers and as seen in stream bluff exposures, further corroborates the theory of a submarginal moraine tramped down by over-riding ice.

In several places, the south-facing moraine-front is very conspicuous. Perhaps as marked a place as any is about two miles south of Powell. For several miles to the south of the edge of the moraine, the level till plain stands at practically nine hundred feet above sea level. One approaching the moraine-front on this plain sees a gentle slope extending east and west and rising northward thirty to forty feet in one-fourth to one-half mile; while to one standing on the moraine and looking southward, the till plain seems to stretch away for a long distance, but on a distinctly lower level. Thirty feet in one-fourth to one-third of a mile gives a slope a trifle steeper than one degree. This is extremely low, but conspicuous among slopes like those of the till plain—two or three feet in a mile. The change of slope is quite marked. The Hocking Valley railroad rises on a long grade of a mile before the moraine is reached, then it enters a cut of twenty feet or more and so rises to the moraine top at Powell. Nearly every freight train from Columbus has two engines to a point beyond Powell. Not alone because of the moraine is the extra power needed, but because the Hocking Valley station in Columbus is on the Scioto flood plain about 720 feet high, and the engine must climb in fifteen

¹ Leverett, F., Mon. U. S. Geol. Survey, No. 41, pp. 525-531.

miles out of the valley, to an elevation of 920 feet at Powell. The average railroad grade is 13 to 14 feet in a mile, while the slope of the moraine is probably as steep as 100 to 120 feet in a mile.

West of the Scioto, the moraine rises 50 to 70 feet in about a mile, or from a 950-foot till plain to moraine summits of 1,000 to 1,021 feet. A rather marked moraine-front can be seen a mile north of Flint on the Big Four and Pennsylvania railroads. These begin to grade half a mile south of the moraine, and make half the altitude necessary before reaching the moraine, then they make a cut until they emerge on the plain north of the ice deposit. For three miles southwest of Galena, along the Cleveland, Akron & Columbus railroad, the southeast-facing moraine-front shows distinctly. The railroad company has cut off the nose of the moraine about a mile south from Galena.

One would be entirely excusable for not recognizing this moraine until across it, if he approached it from the ice side; for it grades imperceptibly into the till plain here and rarely has a kettle on its summit. Levelness or broad shallow sags and low swells characterize the whole surface except along the larger streams where modified by erosion.

The moraine is probably widest at Powell or just east of Alum Creek, and averages over two miles in width entirely across the Hilliards strip. Across the Worthington strip, it averages about one mile in width. It is narrowest east of Africa for two miles, where all unevenness of surface is confined to a strip one-half mile wide, but across the rest of the Westerville strip and on northeastward beyond Galena and Sunbury to the margin of the quadrangle, the width of a mile to a mile and a half is constantly maintained. The moraine was once continuous across the area except for two or three small stream cuts where the Scioto and Olentangy rivers and Alum Creek now cross it.

Phenomena Accompanying the Moraine.

Among the features whose origin is wrapped up in the history of the Powell moraine are a lake (now drained), an outwash plain, and two or three drainage channels. About half way between Galena and Sunbury and nearly parallel with Big Walnut, between the wagon road and the Cleveland, Akron & Columbus railroad may be seen a channel a mile in length and in its middle and southern parts quite distinct. (Pl. 19 A.) It evidently carried water near the ice margin, for a short time, after deposition of drift had begun. Its preservation means that at this point the ice did not again advance over its first deposits. Between Westerville and Africa in a complicated mass of moraine, somewhat modified by stream erosion both during the melting of the ice and post-glacially, two channels now wholly abandoned by water are easily traced. The longer one begins about a half mile south and a half mile east of Africa and continues southward a mile and a half, then turns southeast for a half mile. The shorter one begins one-fourth mile east of the south end of the other and continues in the same direction, southeast, for a half mile or more. These two were probably continuous when made, but their connection could not be established.

Together they reach almost entirely across the moraine and must have been in rather constant use during its building. When the ice was gone, the waters seem to have crossed the moraine in what is now Alum Creek Valley.

East of Flint an area of four or five square miles, partly in each county and extending entirely to the big Powell moraine, has, according to the topographic map, intermittent streams. The land is very level, and surface drainage seems to be poor, but the land is not wet. It is too sandy. Water, which would normally flow away in surface streams, sinks. The soil survey map¹ shows the soil to be streaked, strips of clay loam alternating with black clay loam. Below the black soil the sub-soil is silty. This is all in accord with the conditions, but it should be added that there is considerable fine sand in the subsoil. The area is essentially an outwash deposit of fine material spread as a thin sheet at this point in front of the Powell moraine.

Most of the drainage of the Powell moraine, so far as this quadrangle is concerned, went in the present valleys, for at no other point across the whole moraine-front was any outwash found, save the minor deposits along the present drainage lines. The drainage seems not to have laid down much waste during the making of this moraine, for only very limited deposits occur down the valleys from it. Along the Darbys very little occurs which could be called outwash. Recent stream gravels and sand are found at several places, and possibly some of the areas mapped as outwash belong in this class.

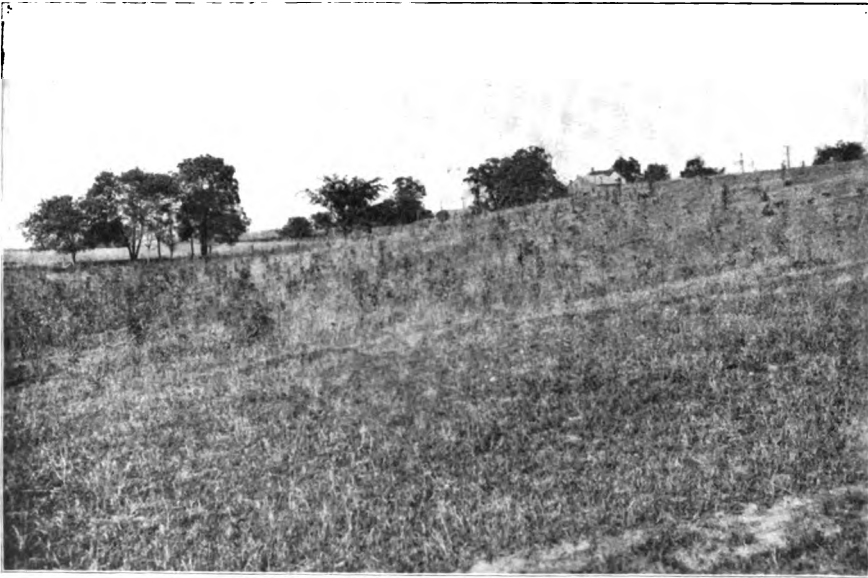
Around Columbus are a dozen square miles of gravel-covered territory. (See map in pocket). Some of this is mapped as flood plain, because at present subject to floods. Beneath the alluvium, however, the gravel is found in almost every cut. The State House well² shows the gravel to extend downward at least sixty feet below the present stream. Its surface, even in undisturbed areas, is lower than the till plain, and over large tracts a portion of the deposit has been carried away. With such a depth, the deposit can hardly be all post-glacial. The lower part may have been laid during a previous ice invasion or even during the oncoming of the Wisconsin sheet. While the ice was melting back from the Westerville moraine and before the building of the Powell moraine, erosion took place; then during the building of this latter moraine, the waste-laden waters deposited in the valley large quantities of sand and gravel; so much, in fact, that the valley was filled nearly level full. Thus it happens that the outwash plain is not quite as high as the surrounding till plain. It is not believed that the valley filled was much deeper than the present valley, possibly not as deep here where the deposits occur, and certainly not nearly as deep up stream toward the moraine as the present ones. The steep grade from the moraine to this point prevented the deposition, while the greater depth here and consequently lower grade for some distance below encouraged deposition.

On the western side of the quadrangle a mile or so south of New California, the moraine seems to have enclosed a basin. It has distinct moraine nearly around it, silts across its floor, and sand around much of its margin as a small beach. Sugar Run enters it from the northwest, sluggishly traverses the whole length and emerges at the south. Since the clays and silts and the beach deposits establish the fact of a former temporary lake, there must have been a barrier across the south side as

¹ Westerville sheet. Field Operations, Bureau of Soils, 1905.

² Newberry, J. S., Geol. Survey Ohio, vol. 1, pp. 113-114.

PLATE XIX.



A.—East wall of an abandoned valley between Galena and Sunbury, west of road. The lower clump of trees is in the channel. The west wall of the valley does not appear in the figure.



B.—Alluvial terrace at Harrisburg. Looking southeast from the road in north edge of town. Terrace is nearly half concealed by the tall corn on the flood plain.



on the other borders. This has been removed and the basin drained after having been nearly filled with sediments and organic matter. There is no delta to be seen at the upper end; on the contrary, the lake plain and flood plain of the stream above, seem to be perfectly graded to the same level. It is believed that the basin is due to uneven deposition of drift, and probably not to an ice block, as the margins nowhere exhibit evidence of having been built against something now gone.

Subsequent Glacial History.

When time enough had elapsed for the building of the big Powell moraine in the ways suggested above, the balance of process was turned—melting exceeded flow—and the margin of the great glacier again began to recede. In this recessional move no stream deposits of any kind seem to have been made within the area. The till plain is continued as between the other recessional moraines and with about the same levelness. No more halts even of the shortest duration are recorded within this quadrangle, but in the territory to the north may be found the records of repeated halts and recessions, until the ice had melted back beyond the divide and the marginal Lake Maumee became possible.

In the conclusion of this chapter on glaciers and their work in the Columbus quadrangle, let it be noted that the events and the succession of events here recorded are a part of a great whole, namely, the story of the Glacial period in America. The facts presented might be duplicated in a dozen quadrangles of the same size along similar zones of the drift-covered portion of North America. No tract would have its record written with exactly the same characters, nor would it tell exactly the same story; yet there would be remarkable similarity. The problem of deciphering the inscriptions, once learned, would be easy in other places and the methods would apply in hundreds of instances.

CHAPTER V.

PHYSIOGRAPHIC HISTORY.

POST-GLACIAL.

Post-glacial history began considerably earlier in the southern part of the area than in the northern, but the total post-glacial time has been so long that any advantage thus gained is scarcely discernible today.

Beginnings of Valleys.

As the ice left the lands, none of the valleys now so attractive and important were present except those used for glacial discharge, mainly north and south valleys; and these must have been very youthful. The lands at first were bare and free from vegetation; but undoubtedly then as now, in front of waning glaciers, the vegetation crowded close up to the ice and possessed all but the newest surface each year. The first plants to grow were not the present flora, but a more northern one which had been crowded south by the oncoming ice, and which was now following its cold usurper back to its early home. As the soil became better and climatic conditions more salubrious with the lapse of time and withdrawal of the ice, the present flora crept in and became adjusted element to element, while most of the more northern plants migrated farther or perished. A few, however, remained to surprise and delight the zealous botanist and testify, with the drift, to the former presence of the ice.

Such streams as the Darby, Scioto and Little Walnut in the southern part, probably extended from the very ice front or even beneath the ice a short distance at times, southward as at present. These streams increased in length as the ice receded, but probably not much in size except as they took on new tributaries because their waters were largely of glacial origin.

The Courses of Major Streams.

Several items have been given which bear on the origin of the major streams. The Scioto and Olentangy seem never to have been marginal in this area, while Blacklick from its sources in the southeastern corner of Delaware County, practically through its entire course was from the start, and even yet is, a rather close follower of the moraine. At a little later stage, Rocky Fork was approximately marginal through many miles of its upper course, although the ice did not halt long enough to leave moraine where the stream now flows. Big Walnut below Gahanna flowed away from the ice front; from Pinhook six miles south-

ward it was a subglacial stream close beside its present channel, while it made the Gahanna esker; from the same point northward six to eight miles it grew as the ice melted out, and later, for the upper three miles or from Galena northward it was marginal. When marginal, its channel must have been similar to abandoned marginal channels noted in the same vicinity except that it was occupied by a stream; and, if streams had persisted in the now abandoned channels, they must have become by today indistinguishable from ordinary present day valleys.

Alum Creek from the turn at Blendon southward three or four miles was in a marginal channel. As the ice melted, the stream dropped to the lower present course and the upper channel was left behind. Farther south it swung across the new till plain in a consequent course to Big Walnut Creek and the Scioto. From Blendon northward to the limits of the area, the stream must have taken its start at the ice margin and flowed directly away, growing as the ice vanished. Its channel through the moraine was once divided; and probably both parts resembled at first the abandoned channels above Westerville, except that they had more youthful slopes than those. Years of weathering and surface wash have widened the channels and matured their slopes.

Scioto Big Run was given its direction by the ice margin and moraine deposition, and it received marginal drainage during the making of the Westerville moraine.

These may all be classed as consequent streams, taking their initial courses across the drift in accordance with, and in consequence of, initial slopes. A few slight, subsequent adjustments here and there have been made.

The relation of these streams to outwash deposits has been watched for carefully. It might reasonably be expected that outwash would be found along each valley down-stream from each moraine. Such, however, seems not to be the case. Outwash accumulates in ready-made valleys or on the plains beyond the moraine, if the slopes, volume of water, and supply of waste are so adjusted as to make it necessary. The scarcity of gravel and sand deposits suggests that the abundance of water was able to carry most of the waste beyond the limits of the area, even with the moderate grades provided for the streams. Boulders along the Scioto and Olentangy below the Powell moraine witness to the fact that the streams carried away all in their courses but the boulders, sorting them out because of their size to be left behind. On the outwash in and below Columbus, the Scioto must have been left, when aggradation ceased, with a braided or divided channel. Evidence of this condition is found in the abandoned channels south of Grandview, and among the gardens south and southeast of the cemeteries. Other cases of braided channels have been treated in connection with the subject of abandoned channels.

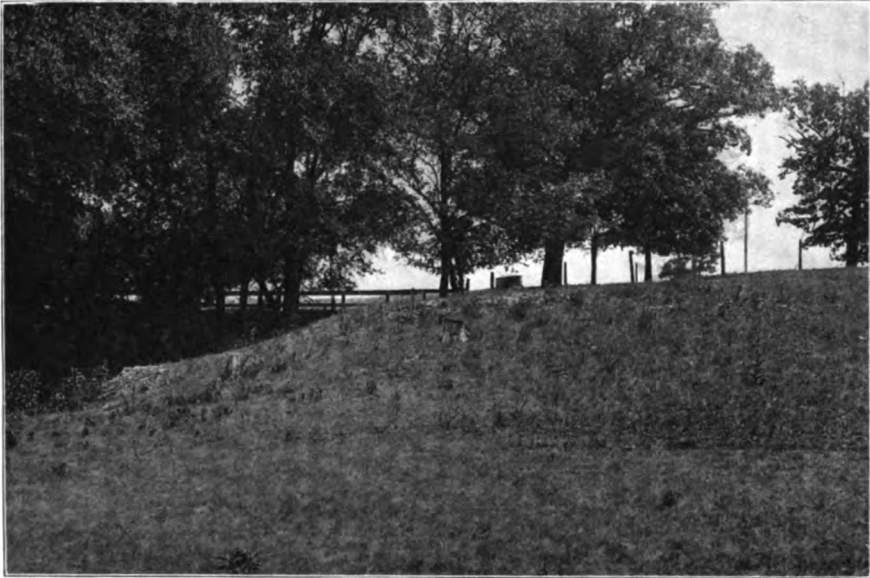
Beginnings of Laterals.

As the streams proceeded to deepen their valleys, each of those with divided course soon got all its water together, taking the channel which in this stage deepened the fastest, and abandoning all others. As these main valleys were deepened, drainage down their sides washed waste in and thus widened them. Then the surface wash became concentrated in places along certain lines and by erosion developed small lateral valleys. These constitute the fringe of subsequent later valleys, so marked a feature along the main valleys in the northern half of the area. (See topographic map in pocket.) There are many of them in the southern half, but they are smaller and shorter and do not show so well on the map. Where the Scioto and Olentangy rivers, and Alum Creek cross the Powell moraine their laterals have so far destroyed the morainic topography that moraine should not be mapped, although till yet mantles the rock in these places. In these gaps in the moraine, probably made by the carrying away of drift, the map shows till sheet.

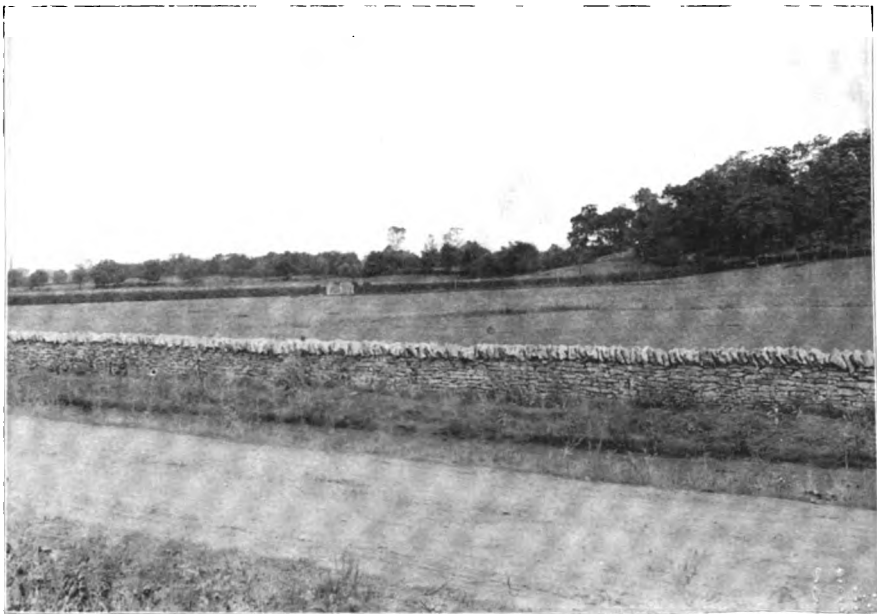
Many of the smaller streams are intermittent, i. e., they do not flow all the time as do perennial streams. This is due to variations in the supply of water—irregularities in rainfall. The absence of springs is especially conducive to intermittency of streams, because such absence leaves them with no supply when dry seasons come. The floors of the channels of these smaller streams frequently consist of a bed of gravel and stones into which the water sinks and creeps along out of sight. Others are floored with jointed and partly dissolved limestone, having secret passages below, which conduct part of the water away. Since these two types of floor are not continuous all the way down a valley but are interspersed with reaches of denser rock, it frequently happens in times of low water that a stream will be visible while flowing over the less porous drift or shales; and then will entirely disappear in the gravel or in solution cracks for a distance, leaving a dry bed to be succeeded again, when conditions have changed, by a stretch having a visible stream.

Alluvial Terraces.

The main streams while cutting down have also cut more or less laterally, and so have widened their valleys and developed more or less of flood plain along the channels. By these two kinds of cutting, they have in many places carved terraces. Around Georgesville are several in drift. Their forms are not clear cut, but indefinite. Similarly, others occur at the junction of Blacklick and Big Walnut, along the latter near Central College, and again south of Galena; along Alum Creek near Linden, above Parks Mills; near Africa and at Cheshire; and two miles above Worthington along the Olentangy. Terraces have been carved in a like manner in gravels and sands in several places. On



A.—Rock defense at the end of an alluvial terrace, near the gate leading to the State Farm, Orient. The upper rock defends the upper terrace; the lower rock defended a lower terrace, but has now been quarried out.



B.—Rock terrace, Marble Cliff. Looking nearly north across terrace top to drift bluffs beyond.

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the Darby at Harrisburg is a fine cluster standing out into the valley from the west side. The stream has repeatedly cut into the gravel here at successively lower levels, but has always swung away and failed to completely remove the deposits. Each time it has left a terrace on a lower level than the last. (Pl. 19 B.) A very similar group juts out into the valley from the east side lapping over the block from the west, so that the stream is obliged to make a very crooked course to get down the valley. (See topographic map.) At the tips of this latter group, limestone ledges are always found acting as a defense for the weaker material. (Pl. 20 A.) If it were not for this rock at critical points, the rest of the gravel must have been cleared away. The defense may be seen in several places at the west end of this group near the railroad bridge and the gateway leading beneath the railroad to the State Farm. These terraces are neat and trim. The front slope of the highest is 28 feet, but to the north where these ledges occur the one big one is divided into three or four steps, too small to be mapped. No such defense was located on the critical points of the Harrisburg group, although repeated diligent search was made; and, in spite of the failure to find a protecting mass of rock, the impression cannot be removed that there are rock ledges here also which may some day be found. Several less definite, apparently undefended gravel terraces occur down stream from these.

In the eastern and southern part of Greenlawn cemetery are terraces, and others occur farther south; still others also occur west of the Olentangy a little above its mouth. These all seem to lack defense and they have not been given the neat, trim form of those cited at Harrisburg. Another indefinite undefended group of gravel terraces occurs along Alum Creek near the Infirmary in the eastern part of Columbus. A very interesting discussion of such terraces as the above, together with the question of the defense, has been published by Davis.¹

Rock Terraces.

Besides the terraces in drift and alluvium there are many in rock along the Scioto and Olentangy shown mostly in the northwest quarter. (See physiographic map.) These rock terraces occur at all possible levels and in all possible vertical relations to the limestone formations into which these streams have cut. The Pennsylvania railway station of Marble Cliff is on one of these terraces. (Pl. 20 B.) At Dublin, the terrace on the east side is 30 to 40 feet above the water and 20 to 200 yards wide. Three to four miles up stream, a large terrace stands about 80 feet above the river. This is the highest, and the lowest is now partly below water at high stages. They have been described in a recent paper² from which the following summary and conclusions are in part borrowed.

¹ Davis, W. M., Bull. Mus. Comp. Zool., Geol. Series; vol. 5, pp. 282-346.

² Hubbard, G. D., Ohio Naturalist, vol. 9, (1908), pp. 397-403.

All rock terraces descend down stream, and most of them descend toward the river. Almost every terrace top is nearer the river level at its down stream end than at the other, hence it follows that the grade of the stream has been reduced since the terrace was made. And further, an analysis of the slopes of the various tops shows that the higher ones descend down stream most rapidly, and the lower ones but little faster than the present water level. The average fall of the Scioto at present across the Dublin quadrangle is about 7 feet, and of the Olen-tangy is $5\frac{1}{2}$ feet, bee-line distances. The upper terraces fall twenty feet in a mile and some of the lower ones ten feet or even a little less. This relation makes it quite evident that the present stream flowing in the same direction made the terraces.

In harmony with the slight eastward dip of the rock strata and the customary streamward slope of the terrace tops, those on the west side are usually structural plains, while those on the east side commonly are not.

The terraces are confined to country whose surface rock is limestone, or limestone with a very little shale cover. The shale alone seems not to be well adapted to terrace formation. Occasionally in the lateral valleys, good terraces are found consisting of Ohio shale from which the thick drift cover has been removed. The shale proving a much tougher material than the drift, the stream has, to date, been unable to make nearly as wide a valley in it as in the drift above. That these shale terraces are largely due to difference in the relative rate of weathering in the shale and in the drift, and not to lateral planation by the stream, is shown by the fact that, in the two or three instances where such terraces appeared, they were similar on opposite sides of the stream. This condition is never true in the limestone terraces. Rarely is there a place found with a terrace on each side, and when opposite terraces do occur, they are of very different height.

That there is neither harmony nor system in the height of the terraces seems to point to the normal cutting of the stream without rejuvenation as their cause. They are not systematically at the top of the limestone, as if due simply to the encountering of rock, but sometimes near the top and sometimes way below it. Nor is there any gradation in the height of the terraces. A high one may be both succeeded and preceded by a low one, or any other succession may exist. The stream is not a systematically meandering one, hence the terraces have no crescentic fronts and terrace cusps. Nor are the terraces due to any rock defense, as are the alluvial terraces cited above. For these two reasons, they lack the neatness and the definiteness, the conformity to pattern, often associated with alluvial terraces. The streams were degrading streams but at the same time were doing a little lateral planation. Hence, when cutting down in the rock they have migrated a little laterally, and have left, as they withdrew, a gently sloping terrace

top with an alluvium cover. Occasionally, it has happened that the stream after swinging one way, has come to swing in the reverse direction, thus partly planing off the first terrace and leaving another on the opposite side at a lower level. Had the ratio of down cutting to lateral cutting been greater, the terraces would have been relatively higher and narrower, and probably they would have sloped streamward more.

The terraces are of marked economic importance, offering good roadways above flood waters, and good building sites above the fertile flood plains, but not so far away as sites on the uplands must needs be. Springs frequently occur at the back side of the terraces, making them still more desirable for residences. The Pennsylvania railroad (Indianapolis division) finds on the Marble Cliff terrace an easy grade from the flood plain in West Columbus up to its bridge near the station and across to the undissected upland west of the Scioto. Finally, most of the limestone quarries of the area are in these terraces, because of the excellent opportunities offered to get at the rock.

Other rock terraces occur along the Big Darby. One is two miles south of Georgesville on the west side and just south of a large alluvial fan. Its top is twenty to twenty-five feet above the water. This is the only one along the Darby large enough to show on the map. A little gravel or alluvium continues the rock terrace at each end. Between this point and Georgesville, a number of miniature rock terraces occur from water level to about 20 feet above. The Darbys have cut through the drift in many places, but have only begun here and there to cut in the rock, hence their terrace series are in a much less advanced stage of development than are those of the two larger rivers. While its terraces are not large and are never far above the water, it seems probable that the time will come when the Big Darby will have so far cut into the rock that its valley too shall be ornamented with terraces of limestone.

Growth of Lateral Volleys.

As the main streams have enlarged their valleys both downward and laterally, and the side valleys have developed, the streams have been getting more and more complete possession of the till plain. A sag or kettle in the plain collects water. When the depression is full, it overflows and the overflowing water carves a little channel away to some growing tributary. Thus, the tributary is lengthened by the addition of a new section. When the addition is completed and water drains from beyond the sag into and through the latter without halting, and on down to the larger stream, this whole lateral valley in which it flows will be narrow at the head, wider where the sag is traversed, and narrow again below it. Many laterals in this way now pass through what were once sags or kettles in the till plain or moraine, and hence

are not systematically larger from source to mouth; nor are they symmetrical. They vary in width, and the stream often lies close to one side with no evidence of its having swung across the valley.

By Springs.—Springs often lead a valley headward. Water flows away from the spring and joins a stream, developing a little valley as far up as the spring. Then earth falls repeatedly into the head of the new valley and is carried away. By this process, which is known as sapping, the valley is elongated, the spring leading it along the underground water course that supplies the spring. A fine example of this phenomenon occurs a mile or more below Harrisburg in the west bluff of the Darby, where a valley a hundred feet long and fifty feet deep has been made by a spring issuing from the contact of new and old drift.

By Headward Erosion.—The universal process of headward erosion is responsible for most of the elongation of tributary valleys. Much has already been done toward obtaining complete possession of the uplands. Yet hundreds of square miles of plain still exist which have been practically unmodified by the streams. Man is aiding the work by making open ditches through the fields and preventing erosion by underdraining with tile. As one follows up the young lateral valleys, their floors in each little tributary are found to approach nearer and nearer the level of the till plain. Usually the rock disappears and the stream flows on drift some little distance below the sources. (Pl. 21 A and B.) Finally the valley, like a vanishing trench, runs out and leaves the traveler upon the upland. This is the level till plain previously described. Thousands of little rivulets form upon it and creep out toward some tributary head, then leap over a little drift fall, a few inches to a few feet in height, and start down the ravine. These tiny rivulets by eating at the ravine heads and pushing the tiny falls back are putting the streams in possession of the plain.

So little progress have the streams made in developing the drainage system that the topography is designated as young. The valleys both of the major streams and of their laterals are in a youthful stage of development, as is evinced by the relatively steep slopes of the valley walls; the narrowness of the valleys; the barrenness of the rocks of the valley walls in many places; the broadness of the interstream areas which contain the inconspicuous, indefinite divides; narrowness, in many cases absence of flood plains; the steepness of the grade of the channels; the paucity of tributaries, and the failure of the drainage system yet to have gotten possession of much of the uplands. Different degrees of maturity are reached by different streams. The major streams, especially along those parts working in drift, have the most mature valleys. In fact, in some places the development is so advanced that the term submature, almost mature, might be applied; while some of the upper ends of the tributaries and upland farm streams occupy valleys in such

PLATE XXI.



A.—Headward erosion valleys as seen from the Baltimore & Ohio Railroad north of Orient. Two branches meet in the center of the field.



B.—A view farther up the left branch seen above.

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extreme youth that there really is no valley at all—only a channel, whose slopes are so short vertically and so little worked upon by the streams that they have not yet reached the steepness considered characteristic of youth. These valleys are too young even to have steep slopes either in their walls or in their channel floors.

Effects on Till Plain.—Two pictures will serve to illustrate what the streams are doing for the plain in the way of dissection. Southwest from Harrisburg a good macadam road leads toward Mt. Sterling. Careful construction and considerable grading have given a good easy highway. The photograph for Plate 22 A was taken about one and three-fourths miles out from Harrisburg, looking back along the road. It shows the ups and downs of this part of the road which are due to the unevenness of the plain, unevenness developed by erosion of small streams leading southeast to the Darby Valley. These streams cross the road nearly at right angles. The plain here may be said to be broken. The picture on Plate 22 B was taken two and one-half miles farther southwest looking northeast, and shows the extreme levelness of this unclaimed portion. Telephone poles, the view of the carriage and the house at the end of the road, show vividly how extremely level and unmodified the plain here is.

Varying Width of Valleys.—A great many of the valleys, notably the gorges, show remarkable variations in width even within short distances, variations which can be traced almost entirely to local causes. Some of these have been noted in other connections on previous pages. One of the prettiest illustrations of this variation is found in the valley of the first stream on the left of the New Albany pike about two miles out from Gahanna. (Fig. 9.) The upper part of the valley down nearly to the town line road is narrow, bordered with practically continuous outcrops of Mississippian sandstones and shales. Then for more than half a mile the valley opens out four to six times as wide and is grassed over completely. No rock can be found in any part of this section, but farther down stream the valley narrows down again for one-fourth mile, and the same shales appear constantly. The variations here are due to the fact that the present valley crosses an earlier buried valley. Where the present valley is in rock, it is narrow; but where the stream has had to remove only drift, filling the old valley, it has been able to open out a wide one. Northeast of Reynoldsburg are several similar illustrations. Between Columbus and Worthington, several of the valleys largely in the black Ohio shales exhibit the same peculiarities. There is usually an abundance of boulders in the stream bed at these wider places.

From Lewis Center westward, a valley leading down to the Olen-tangy has almost continuous rock outcrop in its walls after the rock is once reached. But the valley is first of moderate width for some dis-

tance west of the electric car line, then it becomes wider for a short distance, then narrows to a rock gorge at the bottom and so continues to the river. Examination reveals the fact that in the upper part the bed rock is a black tough formation described in the first part of this bulletin as the Ohio shale. In the middle part is a soft, easily eroded, bluish rock called the Olentangy shale; and by the time the lower part of the valley is reached, the stream has cut through both of these to

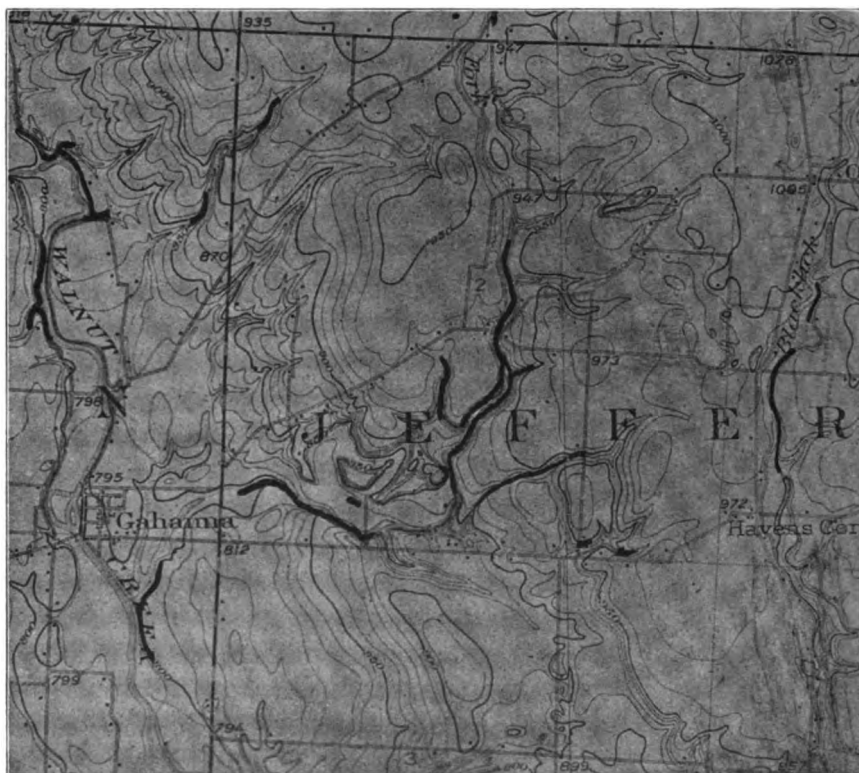


Fig. 9—Topography and rock outcrops (in heavy black lines) in the vicinity of Gahanna and Rocky Fork.

the hard Devonian limestones below, and here it has been able, so far, to carve only the narrow gorge. Many streams tributary to the Olentangy and a few leading to the Scioto illustrate this type of variation.

The large streams as well as the small are subject to these phenomena. At Georgesville, the Darby valley is broad in drift, but a mile south of town, the stream encounters the limestone, and the valley is pinched up almost to a gorge. The Scioto from Arlington and Grandview southward is a broad open valley, but northward it becomes a veritable gorge throughout the whole area; because downstream it is in drift and alluvium, but upstream in the limestones. The Olentangy is in drift



A.—Effects of headward erosion on the till plain southwest of Harrisburg. Sags in road mark places where little valleys have been cut.



B.—Absence of erosion on till plain near Derby, Ohio. Road is very level.



from its mouth nearly to North Columbus; then in Ohio shale, in part at least, nearly to Worthington; in drift here, for two miles;¹ then in the shale, nearly to the north county line; from whence it is in limestone to Delaware. The valley gives expression to these variations in material by presenting corresponding variations in width and general maturity of form. A comparison of the size and depth of the Olentangy and Scioto valleys also shows the effects of rock resistance. Although the Scioto is three or four times as large as the Olentangy, it has a much smaller and even shallower valley in the limestones than the Olentangy has in the shales.

Variations in valley widths have been noted in a few instances where the above conditions do not apply, usually at junctions of streams, or at turns where lateral planation has been specially active.

Many streams run their whole courses in similar rock materials. Rattlesnake Creek is in the Berea or Cuyahoga sandstones almost its whole length; and it has carved a narrow steep-sided gorge which might well be called a box canyon, because its sides are so steep and its walls make such clear cut angles with both the flood plain below and the till plain above. The gorge lies like a trench cut in the plain and is sparsely timbered. A similar valley, but one carved in drift, is that of the Darby at Orient. It is now a hundred feet deep, but many times as wide as Rattlesnake valley; yet its bluffs are as steep as the drift will stand. The Baltimore and Ohio railroad does not descend to cross it, but traverses a long viaduct ninety feet above the flood plain.

A pretty valley entirely in drift leads from a mile or so west of Linworth eastward to the Olentangy. Nowhere is the rock revealed in it. The valley is open; its slopes gentle, except where recently undercut, grassed over or under cultivation; its floor is evenly graded, and the whole valley is beautifully smooth. Similarly, the south valley that leads to the Scioto at the Columbus Fishing and Gun Club, has no rock exposures, but is mantled and smoothed with the drift until it presents most attractive curves and slopes; while the north valley is a rock gorge all the way. Such comparisons as these show clearly the difference between age in years and age in development. Valleys in rock are very young, while those in drift are many times as far advanced; yet in years, all those mentioned are essentially of the same age.

Landslides.

Many of the more youthful valleys have had landslides and now present characteristic topography. In most cases, the sliding has been due to ground water producing springy conditions in the drift, occasionally in rock. About one and one-half miles southwest of Galena along the valley road are well marked landslide surfaces in drift

¹ Orton, Edward, Geol. Survey Ohio, vol. 3, p. 598.

over Ohio shale. Several slides in relatively recent times have occurred a mile or so south of Georgesville along the west bluff of the Darby. On the same side, some four miles below Harrisburg, are many more large drift slides. Some have a growth of young trees twenty-five or thirty years old upon them. Rock slides are known in the gorges tributary to the Scioto and Olentangy. Usually these affect the stream only a few years and are then all washed away, but a few persist for many years.

Water Falls and Rapids.

Many of these youthful valleys have rapids and a few of them have falls, which have gained a little local notoriety. Hayden Falls is perhaps best known. (Pl. 16 B.) The water leaps over a layer of the Columbus limestone after cascading over several layers of the less resistant limestone above the hard one. The fall, which started at the bluffs of the Scioto, has retreated upstream only a short distance. Recently, the water has ceased during low stages to go over the falls, but drops down into joint cracks some distance above the fall and finds its way through them out to the Scioto. Many streams during low stages follow this peculiar habit of losing themselves in cracks in the limestone near their mouths, and then emerging nearer the river or even below river level. In the case of Hayden's or any other stream with a fall from which underground passages have withdrawn the waters, the fall ledge constitutes a natural bridge; and if the lower passage becomes large before the span collapses, a very attractive bridge will result.

Indian Run entering the Scioto at Dublin has two branches uniting half a mile above its mouth. Falls, having retreated from the Scioto bluff up to the junction, divided, and each part has now migrated some little distance up its fork. The fall here has retreated much farther than that at Hayden's, possibly because there is more water. Just west of the new Casparis quarries, three-fourths mile up stream from Marble Cliff and west of the Scioto, a small stream enters the river with a 30-foot fall over the topmost layer of the Columbus limestone; and the same stream has rapids for a hundred yards or more, higher up, over the thin-bedded Delaware limestone. This fall has retreated a little over 100 feet from the Scioto bluff. Slate Run on the east side of the Scioto a mile and a half above Fishinger's bridge, has a small two-step fall over a layer of the usual fall-making limestone. This fall has retreated nearly one-fourth mile from the Scioto bluff. Opposite Hayden's Run is another small fall. Several others occur in the laterals of the Scioto, and a few insignificant ones in the laterals of the Olentangy.

Some falls occur over the top layer of the Columbus, others over different lower layers of the same formation. While the falls are over a layer twenty-five to thirty feet below the top of the Columbus, oftener than over any other, no layer seems to be preeminently the fall-maker. Neither is there any system in the distance the falls have retreated. Some streams have none. The Scioto itself has no fall, but in places has little rapids. It is on the Columbus limestone continuously from

Marble Cliff, northward eleven or twelve miles into Delaware County, where it has cut entirely through the formation to those below. All the lateral streams are in gorges in the limestone, and the upper Scioto has a gorge beneath the top of the Columbus formation. The latter has entirely passed the fall stage, if it ever had falls. Their presence in the laterals would suggest that they may have occurred in the Scioto; but the facts, that there seem to be no common fall-maker and no uniformity of retreat, would indicate that in the Scioto there probably never was more than rapids, unless for a short time at the southern limit of its gorge, and even there it is believed to be improbable.

Many streams have rapids over limestone or shale ledges, and occasionally over the old drift and over beds of residual boulders left by the stream after sorting out the finer movable elements of the drift.

Flood Plains.

A brief survey of the physiographic map or a little observation in the field would show that there is a great variation in the degree of development of flood plain along different streams and in different parts of the same stream. The Scioto has the widest flood plain and is the largest stream, but it also has a very narrow plain in places. For example, about one mile south of the Duvall road across the river, it is less than one-fourth mile wide; while at the Hartman farm and northward to West Columbus, the plain is one and one-fourth to over one and one-half miles wide. This is all in drift. From Marble Cliff northward, the flood plain is quite limited, often wanting, usually too small for cultivation. From Marble Cliff down, the stream is not degrading perceptibly, but is cutting laterally. Up stream the lateral cutting is still very slight. Undoubtedly, the ratio of the lateral to the vertical erosion in recent times is the variable upon which the flood plain width depends. Streams in drift or soft shale, even though small, are cutting laterally enough to have developed flood plains. The plains are made of alluvium, with large recent fills in places. (Pl. 23 A.) In some localities the alluvium overlies rock platforms; in others it overlies gravel; but in either type the deposit is there because of slight aggradation during lateral swinging. In this swinging the stream cuts out rock, drift, or previous deposits from one side, and lays down material on the other, coarser materials near the bottom and finer upward to the topmost level of the highest flood, which is manifestly the limit of stream aggradation. The surface of a newly finished section of flood plain is a little below the level of the plain being cut away, which may give a measure of the rate of down cutting.

Meandering and Abandoned Channels.—The lateral cutting is sometimes associated with meandering, and where so related abandoned

channels, oxbows, and cut-offs occur. One and one-half miles above Harrisburg, the Darby has abandoned a mile of channel in the flood plain. The southern end still contains a pond or lake. The channel northward remains open but is not now swampy nor, except in flood, water-covered. Similar abandoned channels can be found along all the larger streams and many of the smaller ones.

Sand Bars.—Sand bars occur in many places on the flood plains, some five to ten feet above them. These were built during high stages of water. Two examples may be mentioned. One is two miles north of Harrisburg in the Big Darby valley. It rises ten feet above the plain at its north end, but descends southward and blends with the plain at the lower end. The other is in the Scioto valley a mile or so south of the mouth of Big Walnut. This one is about a mile in length, but the former is much shorter.

In a few places, the stream is now braided and aggrading. One to one and one-half miles downstream from Orient, the Darby is so conducting itself because of the undercutting, slumping and rapid erosion of the tumbled waste, upstream. More waste falls in than the stream can carry away, hence it aggrades therewith. The larger streams especially are not now doing much down cutting, as is made plain in places by the large development of flood plain and associated features. The plain is level and only a little above the stream; and there are upon it large alluvial fans. Now the making of these fans must have required considerable time; and they could not be started until the flood plain was finished and the stream had swung away. During their building, the stream has cut down scarcely at all. Hence, it is argued that the streams are not at present actively degrading. Further evidence on the amount of erosion now being accomplished by the Scioto is furnished by studies at Columbus, where the dredging for gravel is being carried on. Gravel is removed from the channel of the stream for commercial purposes, and the depressions resulting do not fill with gravel, nor even with sand, but with mud, showing that the river does not bring to these places any coarser materials.¹

A very pretty feature is the artistic blending of the valley wall with the flood plain. This is most pronounced along the larger streams in valleys in drift, but it may be seen along almost any stream where no recent undercutting has occurred. It is mainly due to the washing and falling in of waste from the valley walls.

In many places along the larger flood plains, artificial levees or dikes have been constructed to keep the water off these flood plains. These are much narrower and have steeper slopes than natural levees.

¹ This item was furnished orally by Mr. A. L. Smith, of the Geol. Survey of Ohio.



A.—Deposit of sand laid on flood plain of Olentangy River on Ohio State University farm. This delta-like form is thick enough to cover corn stubble, and was all laid during one high-water period of thirty hours. (Photo by J. E. Hyde.)



B.—Gently sloping alluvial fan at the mouth of a ravine near Grandview. Several such fans on the Scioto flood plain can be seen from the Arlington car looking north. The ravines furnished the waste now laid in the fans.

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Alluvial Fans.

A glance at the physiographic map will show to what an extent large fans have been formed, but nothing less than a trip along a flood plain can reveal the beauty and abundance of the little fans which universally adorn them. Alum Creek, Big Walnut and, to a less extent, the Olentangy present the large fans. Typical examples may be seen opposite Westerville, opposite and south of Pinhook, and at the mouth of Big Run north of Clintonville. A single large lateral has a simple fan, unless it has been eroded away by the main stream; but a group of laterals, as opposite Africa and again two miles further upstream, build a series of fans blended together at their sides, constituting a compound fan. Sometimes a large lateral of low grade has a large fan, and a small lateral has a small steep fan on the large one. Such a combination occurs on the Olentangy flood plain east side, a mile or so north of the Franklin-Delaware county line. Other fans occur on terraces, as does one along the Scioto on the big terrace east of the river, and two miles above the storage dam. Even up many tributary laterals, such as Springwater and Glenmary runs, the Lewis Center valley and Rocky Fork, fans have been made by their laterals on flood plains and sometimes on terraces. The younger and steeper the lateral that made the fan, the steeper the fan. Some were built in the youth of the laterals; and now in a slightly more mature stage of the lateral, the fan is found to be too steep, so the stream has trenched the fan, deeply at the top and less at the margin, and with the waste removed has built a secondary fan at the margin of the first. Nearly every little ravine leading down a bluff from the uplands and mouthing on a flood plain has a fan at its mouth. Literally, hundreds of these fans may be seen in a few days of travel along valley walls. A ride to Arlington on the Grandview car will suffice to show several very fine examples with radii of 100 to 500 feet and altitudes of five to fifteen feet. (Pl. 23 B.)

Succession of Events.—Some fine lessons in the succession of events and time consumed in making a series of features may be worked out with a study of fans and flood plains. Suppose one finds a group something like that shown in Figure 10, which is a conventionalized sketch of an actual problem found in one of the minor valleys of the area. There were in the field the upland (a) in which the valley had been carved, the east wall (b) of this larger valley, a rock terrace (c) to the left, covered with alluvium, and preserved since the valley was about half as deep as at present. Then there were two alluvial terraces with rock below, (d) the older on the right and (e) the younger on the left, made when the stream had degraded to a still lower level; and (f) the gravel and sand deposits of the present stream level. Three fans occur, a primary (g) on terrace (d), and a secondary (h) in front of its predecessor, and another primary one (i) on the lower plain (e). The gorges (j) which furnished the waste for fan (g), and (k) similarly related to (i), differ in form in accordance with their respective ages.

One of the last features made is the lower flood plain (f), which has willows and sycamores of good size upon it. Another recent feature is the secondary fan (h), which now has a walnut tree upon it over fifty years old. Not much material has been laid around this tree as it grew, hence fifty years ago this fan was nearly as it is now. How long it took to build (h) cannot be de-

terminated, but certainly centuries, if so little has been done while a fifty-year tree grew. Fan (g) was completed before (h) was begun, because it was made by the same stream when the latter required a steeper slope and was aggrading its course across (g). After the stream ceased building and began to degrade, it trenched (g) and made (h) of the products. The change in habit of the stream across the fan is brought about by the reduction of the grade in gorge (j). Fan (g), which must have required much time to build, could not have been started prior to the completion of flood plain terrace (d) and the swinging of the stream away from this east bluff (b); and since that time the stream has been able to cut down approximately from level (d) to level (f), or three to four feet. Between the completion of terrace (d) and the present, the stream has swung to this east valley wall a little farther north and effaced part of the terrace, then swung away, leaving the lower flood plain terrace (e); and since the completion of (e) fan (i) has been made. It is smaller, its gorge is more youthful and it has not been dissected as has (g), all of which indicate its youth and are in harmony with its position on

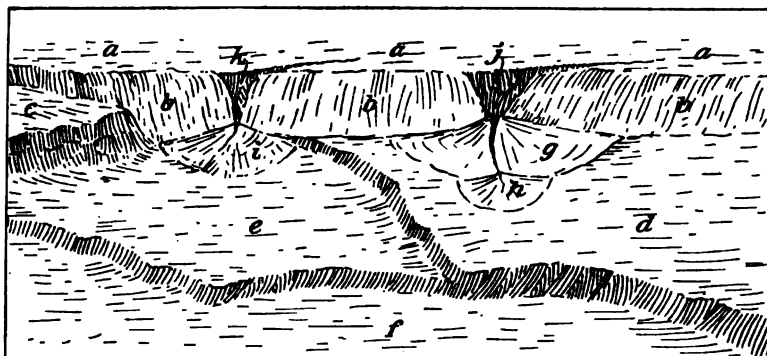


Fig. 10—Birdseye view in block diagram of a group of terraces, fans, and related features, selected for a study in physiographic chronology.

a younger flood plain terrace than that beneath fan (g). Long before the making of any of these features whose development has required so much time, the stream swung off of the terrace top (c) and then returned on a lower level and trimmed its front slope. This present front slope is too steep to date from so remote a time; hence, we may infer that the stream retrimmed it when it swung east and made terrace (d) or terrace (e). And the main valley, carved in the upland till plain, must have been as deep as terrace top (c) is below the upland when that terrace was begun. It would now be possible to state the time of making any one of the features with reference to that of any other, and to state their ages in relative terms.

That the fans were made by the streams leading out of the ravines across them, may be inferred from a long line of evidences. (1) The material of the fan is the same as that removed to make the gorge. (2) It is distributed and deposited as a stream emerging from a steep-floored ravine upon a level plain would do it. (3) Fans are almost universally present at the mouths of ravines unless for obvious reasons it is impossible for one to exist there. (4) Fans do not occur in other kinds of places. (5) Fans in any given locality are consistent in size, form, and materials with the ravines above; i. e., large ravines have large fans at their mouths. Ravines with easy grades have fans of gentle slope and fine material and vice versa. (6) At certain seasons one can see the stream in the ravine pick up materials, transport them and lay them on the fan.

Fans have some economic significance. They make easy grades for roads from the flood plain up the lateral valleys. The electric car line from Columbus to Arlington uses one to help get from the Scioto flood plain up to the till plain level from which the "grandview" is had. In

many instances, they have furnished building sites safely above the floods or malaria of the lower flood plains upon which they rest. They have been taken for pleasure shacks, for stock yards with the pasture below, and for sawmill sites while the flood plain and hillside lumber was being worked up.

Changes on the Till Plain.

In most respects, the unclaimed parts of the till plain have suffered during post glacial time the least alteration of any part of the region. Yet, even on these level upland areas there has been considerable change locally. While the valleys were being carved, terraces trimmed out, flood plains constructed and adorned with fans, and lateral valleys developed, surface wash has carried a little of the finer materials from the higher swells of the till plain into the low places and leveled them up, at the same time leveling down the swells. Thus, many kettles too have become more or less completely filled. Some kettles, however, containing water, have developed swamp conditions and to this day are haunts of the blackbird, muskrat, crayfish and frog, together with the cattail and sedges. Such swamps can easily be found, and many of them have been mentioned on previous pages. Other kettles have developed peaty conditions and today present young peat bogs. Probably the best example of this feature occurs about half way between the Scioto and the Olentangy rivers, a little west of Seagrave and four and one-half miles northwest of Columbus. Others are to be found just west of the Scioto on the upland plains both north and south of the Franklin-Pickaway county line. Recent effort has been made to drain some of these.

Peculiar Valleys.

1. **Rocky Fork Above Gahanna.**¹—Several valleys merit special consideration because of the apparent abnormalities which they present. One of these is that of Rocky Fork, which enters Big Walnut at Gahanna from the east. The upper course to a point some three miles from the mouth, is in drift touching rock occasionally. Then the stream is on the sandstones and shales, and has a narrow, rocky gorge for about a mile. At this point the valley widens, rock may be found only on the east side, and gentle drift slopes border a broad flood plain on the west side. (A, Fig. 11.) This continues for possibly half a mile, when the valley again becomes much constricted, and rock in steep cliffs stands on each side. The throat (B) is some 500 feet long, beyond which a broad valley with a valuable flood plain succeeds, and the rock is not found in either valley wall until near the swing-bridge, where the chocolate shales abut against the drift (C). (See p. 60.) The contact is a south or southeast sloping surface, as if the shales had been eroded from that direction to this point, and then the drift put into the valley thus made. (Pl. 16 A.) The branch (D, Fig. 11) has no rock exposed at any point, and wells along the highway eastward even beyond the schoolhouse do not reach rock even at depths greater than the present valley. At the down-stream entrance to the throat mentioned above, and on the east side of the Fork the rock-drift contact is a south facing slope. The little stream (E, Fig. 11) is on rock nearly to the mouth, but the last 600 feet or more is in drift. It

¹ Most of these little problems have been worked over repeatedly by students, but none of them have ever been published.

seems probable after examining the rock distribution (Fig. 9) that the preglacial (or interglacial) valley here bends northward a little from a westerly course and is intersected by the postglacial valley. Possibly the broken line (Fig. 11) may represent the north wall of the buried valley.

More peculiar is the abandoned valley behind the hill toward which the swing-bridge path leads. This channel is over a mile long and from 300 to 1,000 feet wide. It joins the present valley at each end at points less than one-fourth mile apart. The eastern or upstream end (F) is about twenty feet above the present valley flood plain, while the western end is twenty feet lower and not more than eight or nine feet above the present adjacent flood plain. The latter descends some ten feet between the two entrances to the abandoned channel.

It seems probable that Rocky Fork once flowed through this abandoned loop, but at that time it did not take its present course at the suspension bridge. In the course of time, the curve near the bridge where the stream turned north, by undercutting, pushed westward; and the curve, where the

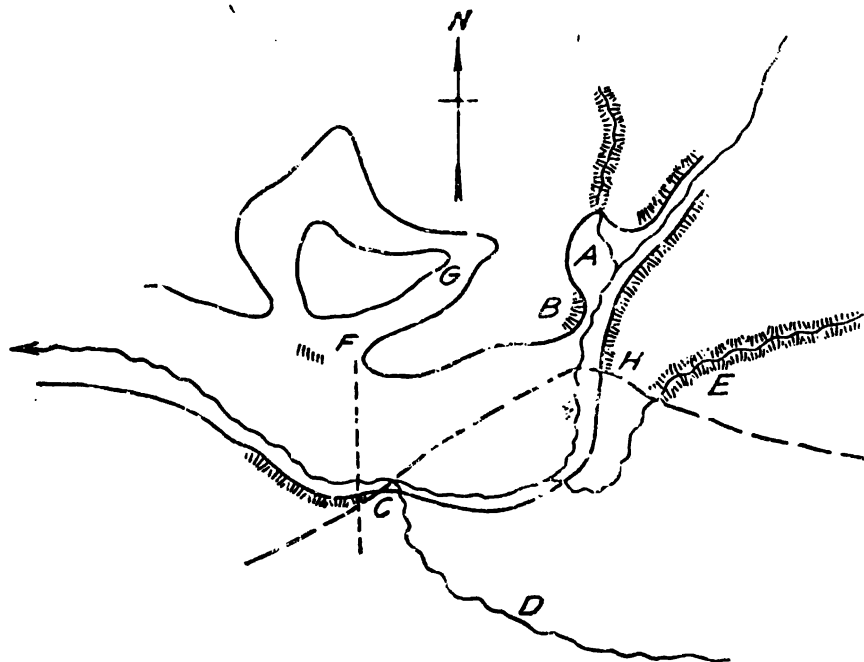


Fig. 11—Sketch map of salient features of Rocky Fork. Smooth line, bluffs, crinkled line, streams; hachures, rock; heavy broken line, probable north wall of buried valley; light broken line, suspension bridge and path.

stream emerged from the now abandoned loop and turned west, by cutting eastward, approached the other curve. When the two curves met, the stream on the west was some twenty feet lower than that on the east side, i. e., equal to the fall of the stream in a mile-long journey around the loop. When the partition between the curves broke, the water abandoned the loop and took the shorter course. In this new course, the stream finally swung laterally and widened its valley to the present limits. Not much down-cutting has been accomplished since this diversion, but the fall at the cut-off has been distributed, and the average grade of the stream in this part has been somewhat lessened.

The main points which lead to this interpretation follow. (a) A marked similarity exists between the abandoned loop and other valleys. It is evidently a stream valley. (b) The slope of the abandoned valley floor is down stream, but with a steeper slope and a higher level than has the present stream. This

condition must have existed, if the stream went through the loop in earlier days; for all the streams in this vicinity have been lowering their beds and reducing their grades. (c) At (G, Fig. 11) the abandoned channel has boulders in it, as have present stream valleys. (d) It is manifestly not due to deposition, although all surrounding valley walls are of drift. The cut-off must have occurred a great time ago, because the new course is now nearly as well matured as other parts of the valley continuously occupied; while the abandoned part has no steep, recently undercut slopes, but all are evenly graded. Moreover, a good-sized fan has been built on the floor of the abandoned valley.

The broad section of the Rocky Fork valley (A, Fig. 11), above the throat, is due to a large curve in the stream now abandoned. This one differs from the one just described, in that the stream cut out all the land in this loop and left no hill. The plausibility of the explanation above for the isolated hill and abandoned valley seems greater when it is noted, that, if this loop

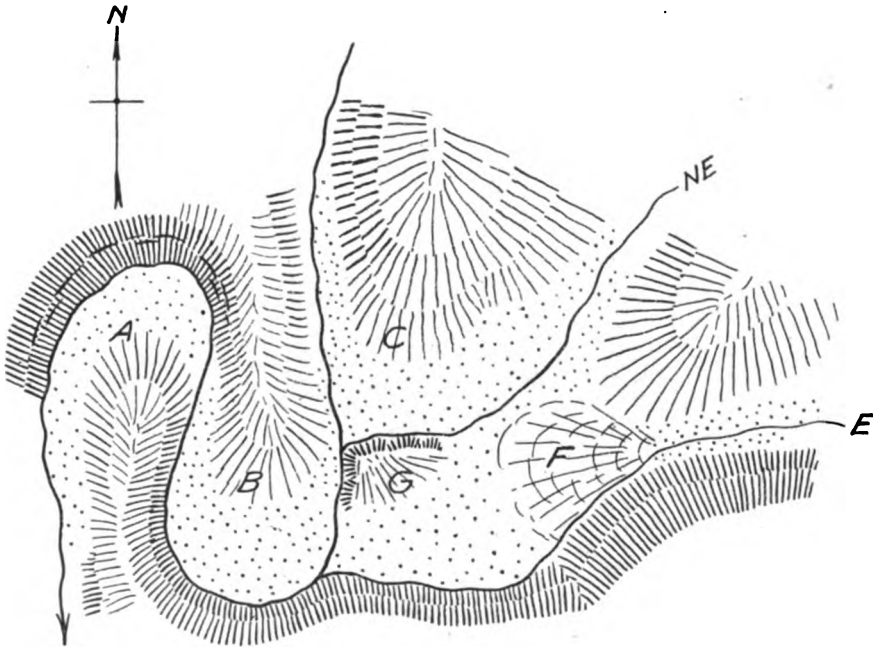


Fig. 12—Hachure map of region in north branch of Lewis Center. Stippling more or less level flood plain deposits. Hachures, rock slopes of various degrees of steepness, usually mantled.

(A) had cut through to (G) before the other loop had cut itself off. the throat would have been deserted and the peninsula-like mass of land now carrying the tree cliff would have become the isolated hill, while a horse-shoe-shaped, abandoned channel would have extended from (A) through the throat (B), past (F) to (G). Undoubtedly, the absence of rock in some portions of this valley, due to the encountering of the buried valley, has been a factor in the development of these peculiarities.

2. Lewis Center Valley.—Two rather unusual features in this valley merit mention. They are both to be found up the north branch fully half a mile from its junction with the east fork. In this vicinity, the valley, wholly in the black shale, widens out to two or three times the width, either above or below the place, and the stream describes two closely compressed, deeply entrenched meander loops. An isolated rock hill stands here in the valley between the mouths of two laterals, which enter from the east and northeast. The problem is the explanation of the isolated hill (G, Fig. 12). The streams must have started with easy grades on the till plain, and as time went by,

they incised their channels into the rock little by little. Lateral planation perpetually on the same side during the long continued down-cutting has accomplished results which the stream could not attain, cutting alternately on one side and then on the other. The big stream loops, which swing around curves (A and B), have enlarged and slowly slipped off the spurs, which now extend far out into the loops. The necks of these tongues are narrowing, and may some day be cut through. Streams (NE) and (E) arriving from their respective directions, entered the main stream with a narrowing ridge between them. Each stream has gradually slipped southward (NE) over spur (C) and (E) over spur (G), just as the loops slid off of their respective spurs, leaving similar long, gentle slopes descending southward; and each has undercut on the south side, making a steep cliff. Stream (E) has been more migratory than the others, for it and stream (NE) have succeeded in cutting out the rock between them near (F) and thus have isolated the hill from the end of the spur between them. Since the isolation both the main stream and (NE) have been planing off the hill; and (E) has deposited material for quite a fan (F), as it comes out of its gorge upon the flood plain.

The other unusual feature is a hanging valley and cascade a little farther up this same branch. A stream with little entrenched meanders comes down from the west and leaps over an undercut bluff ten or twelve feet high, into the larger stream, while a similar little valley with curves like those of the entrenched meanders, extends from near the fall along the bluff southward perhaps a hundred feet. This short valley does not connect with the small valley from the west, though at one time it may have done so; but both ends of it connect with the main valley. It has been suggested that this short valley represents a former course of the main stream or the course of a part of the main stream. It seems more probable, however, that when the main stream had the course of the broken lines (A and B, Fig. 13), the little stream did not terminate at its present mouth (C), but turned on land now cut away, and passed through the abandoned short channel and entered the main stream near (D). The same undercutting by the main stream which tapped a meander of the lateral, cut away the former mouth of the stream from D to D'. This explanation is supported by the following facts: (a) The main stream manifestly has been, and is undercutting. (b) The meanders of the lateral and of the abandoned channel are similar as to size and stage of development. (c) The abandoned channel descends from (C) to (D) at about the same rate as does the present channel of the little stream. That the mouth of the lateral has been undercut is shown by the fact that it is now, at (D), a foot or more above the main valley floor. A formula for the height of the hanging valley in a case of this kind may be stated as follows: The mouth of the lateral valley now hangs as much as the fall of the lateral from the new mouth to the old, minus the fall of the main stream between the same points and the amount the lateral has cut down since the capture, and plus the amount the main stream has cut down in the same time. Certain obvious substitutions must needs be made, if the main stream has aggraded; but such a variation would be rare, because an aggrading stream is not liable to undercut in this manner.

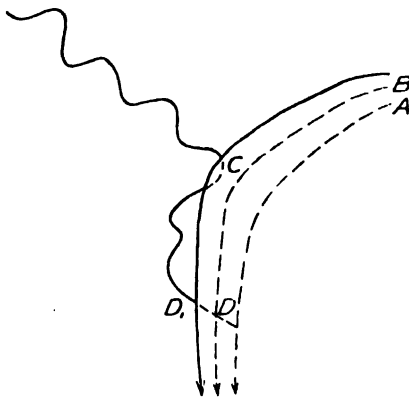


Fig. 13—Map illustrating one method of stream capture shown in north branch of Lewis Center Run.

In the valley of Glenmary a short distance below the electric line, is a case very similar to this, except that just before the streams had completed the work, man aided by a little cutting and filling.

Back at the steep bluff north of loop (A, Fig. 12) a stream enters in a hanging valley much like the above; but in this case the stream formerly entered farther up stream (Fig. 14), rather than farther down stream, i. e., along the broken line. The formula for the height of the fall or amount of the "hang" of the lateral, could be stated for this case also.

3. Solution Work.—Sinkholes, mentioned in another connection (p. 64), are very numerous west of the Scioto and northward from Marble Cliff (Fig. 15), and a considerable number of them occur west of the Olentangy from two miles south of Hyattsville to the northern edge of the quadrangle. The solution work accomplished by ground-water moving along joint planes, to which these sinks are due, must have occurred before the last advance of the ice and possibly before any advance of it. They certainly represent a long period of ground-water erosion, and could not have come into existence while the striations on the rock surfaces nearby have remained almost untouched. That they are limited to the areas sketched above is true, because only here has the post-glacial surface water found its way through ready-made passages to the rivers. However, subterranean passages of the same sort are known in many other places, and no doubt they exist all over the area immediately underlain by the Devonian limestones.

Their relation to valleys is illustrated in an interesting case a mile north and a little east of Hyattsville. The first run south of the east-west highway, leading down to the Olentangy, has a big sinkhole into which the drainage for over half a mile pours. The valley increases normally in size, depth and maturity down to this point, where it is a broad, deep valley with a large capacity for water. But immediately below the sink, the valley is ten feet shallower, and there is not much channel. Water all goes down the sink under ordinary circumstances, and there is none to make a channel below.

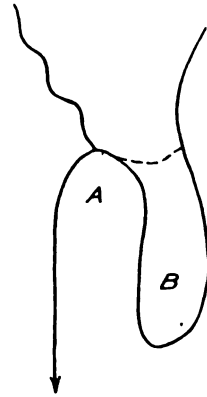


Fig. 14—Map illustrating a second type of stream capture in north branch of Lewis Center Run. Same part of stream as Fig. 12.



Fig. 15—Partial view of a sinkhole in limestone on the farm of Mr. Schrumm west of railroad bridge at Marble Cliff. Horizontal layers of limestone show from bottom of pit nearly half way to the top. The dark place at the right of the stones marks the entrance to a passage leading westward many feet along a joint plane.

During rainy weather, water collects in the hole and goes down as fast as the passage will permit; but if the pit fills full, it sometimes requires a day or two for all standing water to drain away. The water is said to emerge and enter the Olentangy by means of a spring at low water stream level. Another similar large sink in a valley occurs about a mile further south. A third fine example is just south of the road leading east, one and one-fourth miles south of Hyattsville. Here, the sink takes all water collecting in the channel above it. The valley below is not so deep as above, and is beautifully graded and grassed over and has no channel at all. Side valleys have large fans spreading out across the valley floor. Farther down, a tiny stream again begins in the valley and flows out to the mouth at the river. Water must have gone all the way down the valley once, and after the valley had reached about its present size, the underground passage was found, which has been used ever since.

Rows of sinks sometimes occur with no surface connection, but with unquestioned subterranean communication. Other sinks occur with valleys leading to them and absolutely no sign of one beyond. Such is the case a mile or more northwest of Dublin, near the schoolhouse. Undoubtedly, a considerable number of the springs known along the western Scioto bluffs are outlets for sinkhole drainage, and obviously should be avoided as drinking places.

Valleys and Deforestation.

A century ago, nearly all this region was more or less densely forested. Valleys had become adjusted to that condition. The change to the present farming condition has brought about considerable alteration in many of the streams and corresponding changes in the valleys. If timber is removed, water moves over slopes more freely and carries waste down to valley floors faster than streams can remove it. Hence a considerable number of valleys have been aggraded and do not show rock at the bottom. Several of this type lead into the Olentangy from the west, a little south of Hyattsville, and others lead into Alum Creek opposite Africa. Those thus aggraded are level floored in cross-section, and, if pastured and kept clean of brush and weeds, present beautiful grassy slopes and floors. Many still forested have not been aggraded, and others deforested and now reclothed with new growth of timber are being re-excavated. Those in a brushy condition and unpastured are often springy and swampy because of plant interference with drainage.

Relation of Present Scioto and Olentangy to Preglacial Valleys.

It has long been believed that this region held the key to the problem of the preglacial Scioto or of the drainage of Central Ohio, and during all this work care has been taken to find, if possible, a solution to this problem. Many items have been collected which have a bearing on the problem, some directly, some rather remotely; and it will be the purpose of this section to set down in order the facts and arrive at a probable conclusion.

It is well known that the present topography descends southward over nearly the whole area, and westward over a small strip along the eastern side. The only exception to this last statement is between

Pickerington and Waterloo where the surface averages about 800 feet. It has been determined that the rock topography also descends in the same directions. (Pl. 15.) Reference to this map shows the rock altitudes across the north, so far as known, to be uniformly above nine hundred feet except for two well records one and one-half miles apart between the Scioto and Olentangy. This statement excludes the present valleys of the Scioto and Olentangy rivers, together with Alum and Big Walnut creeks, the first three of which are in this section on rock and have bed rock high on both sides, indicating that they are in valleys of their own making at these parts; while the latter seems to be entirely walled and floored with drift, but has cut only to 900 feet here. It will be shown that the present valleys are the work of the streams in them. Therefore, it does not seem possible that any stream of these larger sizes could have come into the area from the north, and certainly none could have left there.

Along the western side, many well records and rock outcrops give figures for the top of the rock as shown on the map. (Pl. 15.) No reading along the border is low; but one to four miles in from the border and near the northwest corner of Franklin County, several well records show rock at or near the bottom. In all such wells the rock surface is between 700 and 800 feet above sea level. Rock topography east and south of them shows no place so low by scores of feet. Since there must be an outlet for the region somewhere if it is stream made, it must be sought to the west and southwest. Three wells in this group show rock surface lower than the present Scioto, which is now in a narrow rock gorge in this latitude. The supposed course of the drainage for this pre-Wisconsin depression is shown on the map (Pl. 15) by a broken line.

Between the Scioto and Olentangy, nearly two miles north of Powell, a well reached the rock 735 feet above sea level, or about 40 feet below the level of the Olentangy, which is on limestone and has here carved a deep rock gorge. This rock surface is also about 60 feet below the limestone floor of the adjacent Scioto. At Powell, the wells reached the rock at 800 feet above sea level. Streams east of the well reach it at 850 feet. Its surface seems to descend westward as if on the slope of a valley, hence the broken line indicating the probable course of a valley is drawn west of Powell. North and west of Elmwood (Linworth on the Hocking Valley railroad) the rock is very near the present surface, and 815 to 890 feet above sea level, even close to the Scioto; hence it would seem that no buried valley exists between Elmwood and the Scioto. At Elmwood, the rock surface is known to be only 700 feet above sea level and lower than the Olentangy River in the channel between Elmwood and Worthington. Hence, the broken line is made to cross the course of the Olentangy and pass near points eastward where the rock surface is known to be less than 750 feet.

Another line of low levels can be traced from northwest of Westerville, southeastward through that town, and back to the west side of Alum Creek, thence southward to join the line just traced, a mile or so south of Minerva Park; whence the course of the combined channels starts south-southeast by south and is lost. The channel leading westward from beyond Gahanna (Fig. 11) may well be supposed to unite with this one somewhere west of Gahanna. A group of deep wells west of Clintonville and the Olentangy found the rock surface at 760 and 695 feet above sea level and descending southward. Since no well was found in the rock southeast of this point toward the center of the city, and since the State House well found the rock at 637 feet above sea level, the broken line is drawn to indicate a drainage line leading southeast throughout the city. This line and those left farther northeast (Pl. 15) seem to be headed toward the supposed "Newark River" valley, which may easily enter the area from the east between Reynoldsburg and Canal Winchester where the rock surface is known to be low. But so many records of the rock surface along the western side of the area were obtained, with none low enough by 100 to 150 feet to permit the drainage from such a valley or even the valley at the State House to escape, that it is believed that no considerable valley leaves the area westward. Since the rock seems to be generally out of reach by present wells through the central part of the southern half of the area, and to lie very low where found, it is believed that the exit for the preglacial and probably interglacial waters was southwestward. Where they went from there is not a part of the problem of this bulletin, but westward connections have been suggested by Dr. J. A. Bownocker² and W. G. Tight,³ which seem entirely satisfactory so far as our local evidence is concerned.

Further evidence confirming this interpretation of the course of the old "Newark River" valley is contributed by two well records found beyond the boundaries of the area. The first well is three and one-half to four miles south by southeast from Pickerington, not more than one and one-half miles from the eastern side of the area and directly in line with the valley as suggested. The well is 232 feet deep and did not reach rock. This puts the rock floor here at less than 600 feet above sea level. The second well is one mile southeast of Ashville, about three miles beyond the southern boundary of the area and east of the Norfolk & Western railway. It is 212 feet deep and ended in fine sand without striking rock. This places the rock surface at less than 500 feet above sea level here. The so-called Newark Valley belongs genetically with the long,

¹ Read, M. C., *Geol. Survey Ohio*, vol. 3, p. 348. Tight, W. G., *Bull. Sci. Lab. Denison Univ.*, vol. 8, pt. 2, pp. 47-59; also vols. 9 and 11. Tight, W. G., *Prof. Paper U. S. Geol. Survey*, No. 13, pp. 19, 23.

² Bownocker, J. A., *Am. Geol.*, vol. 23, pp. 178-182. *Ohio Acad. Sci.*, Sp. Paper No. 3.

³ Tight, W. G., *Bull. Sci. Lab. Denison Univ.*, vol. 8, pt. 2.

gentle, mature slopes discussed on pages 56 and 61, and not with the steeper slopes of interglacial valleys. A comparison with the rock slopes and the abandoned "Newark Valley" between Hanover and Trinway will make this fact clear.

While two or three main buried lines of drainage are suggested above, it is not asserted that these were all used at the same time, nor when any of them were used. Nor is it asserted that these are all the drainage lines now buried. Previous pages of this report mention others, and in the area there are at least thirty known buried valleys. There may be others as large as some of these, but evidence is not sufficient to show even their probable courses. In tracing these lines, only borings are used which have gravel or sand at the bottom or on the rock if they enter it, from a belief that such sections are more liable to represent old valleys.

Present Scioto and Olentangy Valleys Postglacial.

Resuming the record of these rivers where it was dropped (pp. 86, 87), it will be shown that their valleys are largely postglacial, even though they intersect earlier valleys occasionally. The Scioto from the city south does not touch rock, although its bed is lower than known rock on either side (Pl. 15), hence it must lie in a former lowland area. This may be considered a valley, at least from Columbus southward to its intersection with the "Newark River" valley, probably near the southern border of the area. The present valley through this portion is all in drift, hence must be recorded as postglacial in a filled earlier valley.

North of Columbus, between the streams, there are several places whose rock floors are below the present channels, and yet the latter are on rock, and, for the most part, in rock gorges. It hardly seems possible that these present valleys are old ones re-excavated, when there occur so many depressions below their levels; and this possibility seems still more remote, since we can in places connect up the depressions as a system of valleys lying crosswise some of these present valleys, but at lower levels than they at the intersections.

Further evidence supporting the supposition that these streams have made their own valleys, since the Wisconsin stage is found in the rock terraces. As shown on another page, (pp. 89, 90) the terraces in the limestone along the streams occur at all levels from that of the present stream up to the level of the surface of the rock below the drift; they systematically descend down stream faster than the present channel descends, and the upper ones have the steeper slopes down stream. Hardly could a stream get into an earlier valley, and clear it out, and find the features so thoroughly in accord with itself. In addition, if the valley with its terraces was here before the glacier made its last visit, the terraces should be ice trimmed, smoothed or striated. Not a

terrace has presented a striated surface to view, except a high one (820 to 830 feet) near its bluff side about opposite Hayden's Run.

Quarrymen were recently stripping off the mantle from the rock bluffs west of the Scioto about opposite Powell at an altitude of 80 to 100 feet above the river and 860 to 880 feet above sea level. The rock revealed was stream worn, but had no glacial markings of any sort. The terrace on the opposite side is about the same height.

The broad rock terrace between Slate Run and Fishinger's Bridge descends eastward, away from the stream as well as southward, and has a large sinkhole in it. Borings and wells east of it show the rock surface there to be lower than the terrace top, and the wells cited above, still further east, show the rock surface to be even below stream level. It seems here that the river barely missed getting into an old valley. After cutting down to this terrace which must have been a pre-Wisconsin rock surface, and stripping off the drift, then trimming the terrace a little, it swung off westward and made its gorge on that side, instead of sliding on down toward the east where the rock surface is so much lower. The possibilities suggested and the discordant slope of the terrace show what one might expect to find, were the present stream usually encountering a buried valley. The accordance everywhere else between stream and valley argues for the postglacial origin of the valley.

Again, neither the Scioto nor the Olentangy valley have led the ice forward resulting in a protuberance of the moraine. If there had been large valleys here preglacially, the ice should have pushed forward into them and should have built a protuberant moraine at such places. None of the present valleys has such a scallop on the moraine, nor could the buried valleys noted have been very broad, for they have not modified the ice-front either.

Forecast.

If one fully grasps the idea of development of physiographic features and succession of physiographic events, resulting in the evolution of present out of past topography, it is but an easy step to the conception of a future for the present topography. We have come upon the stage when the features of the present cycle are yet in youth. Their history is but begun. While they have had a past of considerable length, they also have a future; and, if uninterrupted, the future will be vastly longer than the past. Our acquaintance with this region may be compared to one's meeting a child for a day or two and hearing the sketch of his life down to date. Such an acquaintance with him might give one a glimpse of what he may become—a basis for a forecast of his future, provided, of course, that one had seen many examples of boys grown to men or knew the principles involved in such growth.

This region being in youth and under the influence of streams in a moist climate may be expected to continue to develop into maturity and pass into old age normally, if the conditions do not change. Climatic variation, a return of glaciers, or the incoming of arid conditions; or elevation, or depression of the lands; all of which have happened to the region, may interrupt the normal processes; but the forecast may ignore them at present and try to sketch what may come with a continuance of present conditions.

A few stream adjustments may be anticipated, but in a level region of such simple structure but few need be expected. It seems reasonable to predict a change some day between Alum and Big Walnut creeks south of Blendon. The former has been recently undercutting on its eastern side; the latter has a large loop or curve westward which may be still farther developed and pushed westward. Since but about three-fourths of a mile of territory now remains between the streams, and since Alum Creek valley is already 20 to 25 feet deeper than Big Walnut on the opposite side of the interstream area, one may expect Big Walnut some day to break through and enter Alum Creek, abandoning its own channel from this point down.

Another place where a change may some day occur is between the Scioto and Big Walnut at Shadeville. The streams are now not more than a mile apart, and modified drift constitutes the only barrier between them. The Scioto flood plain is about twenty feet lower than that of Big Walnut, hence, when the barrier is planed off, the new junction will at once become effective.

A third similar place is in connection with two small streams a little over a mile north of Reynoldsburg. Both are undercutting on their adjacent sides, and less than one-fourth mile remains between them. This adjustment may precede both of the others, because no rock seems to exist between them as high as present stream levels.

These predicted changes are somewhat phenomenal and the ordinary, gradual, every-day, developmental changes are really much more significant; and attention may now be turned seriously to them.

Streams will continue to widen and deepen their valleys, thus reducing both the steepness of the grade, and also the steepness of the valley walls. With wider valleys will come wider flood plains, a few more terraces, more meanders in the streams and larger but flatter alluvial fans on the flood plains. Laterals will multiply, and branches on the laterals will develop to the second, third and fourth orders at least, until by headward erosion the little tributaries will come to drain all the interstream areas. Waterfalls and rapids will be made to retreat upstream, until the layers that make them are intercepted by the bed of the stream which of course is higher up stream than near the mouth. Flood plains will come into the tributary valleys and into their branches. The upland will become more and more dissected; the interstream areas

smaller and more and more serrate-margined; the divides sharper and more easily found; all upland lakes and swamps will be drained and no level tracts of land will remain, but all will be on slopes. Finally, flood plains on the stream level will be the largest plains and will have the gentlest slopes; valley walls will become very gentle and will stand far apart and be thickly mantled with waste; and the remnants of the upland plain (the till plain of today) will be restricted to broad, low, uneven-topped ridges, or rows of isolated hills, as far from the streams as possible. Streams will no longer be subject to destructive floods and all change will be exceedingly slow.

PART III.

ECONOMIC GEOLOGY.

By J. A. BOWNOCKER.

CHAPTER VI.

The economic materials of a Geological nature within the area included in this bulletin are of the commonplace variety. Of the fuels, coal, oil or gas, there are none, and the same is true of the metals. However, the materials are of decided value and bid fair to enhance with increasing population and the extension of business. The most valuable asset by far is the fertile soil. Second in importance is the limestone which underlies the drift in the western half of the area and which is now worked on a great scale. The other materials are of lesser value. The list and the order of their review in this chapter is as follows:

1. Stone.
2. Clay.
3. Sand and gravel.
4. Search for oil and gas.
5. Underground waters.
6. Soils.
7. Agriculture.

STONE.

As already stated in Chapter I. the western part of the territory discussed in this bulletin is underlain with the Monroe limestone, or as it was formerly called the Lower Helderberg or Waterlime. Thus far this stone has not been used as a building stone or for other purposes. Farther east the Columbus and Delaware limestones outcrop, especially along the Scioto River. As is shown in the following paragraphs, one of these, the Columbus, is extensively quarried for a variety of purposes. Still farther east the Berea grit is found at the surface or just below the drift, and while it has a little value it is as nothing compared to the same formation in northeastern Ohio, forming, as it there does, one of the finest building stones in this country.

The Columbus Limestone.

Characteristics.—Economically this is one of the important limestones of the state, being used for flux, buildings, ballast, roads, walks, concrete, lime, fertilizer and in the manufacture of glass and soda ash. Quarrying of the stone for buildings and for lime began in the early

days of Columbus, but the work did not become extensive until about fifteen years ago. Now it is the basis of one of the large industries of central Ohio, though the prime use of the stone is no longer the same as in years gone by.

The rock is fairly even bedded, but the layers vary much in thickness. (Plate XXIV.) Thus at Marble Cliff the range is from less than one foot to more than six feet, the thickest layers being below. The rock is strong, meeting in this respect the severest demands of the architect or engineer. The surface of the layers varies somewhat, giving rise to such names as rough rock, hackletooth, smooth rock, etc. Occasionally it is quite crystalline and takes a fair polish. In fact some of the beds were once thought to be marble, hence the name Marble Cliff. The color ranges from buff to blue, the former predominating. On exposure the shade may darken and often becomes mottled.

The composition of the stone varies from place to place and from layer to layer, and sometimes the changes are notable. Thus the "bone-bed" is high in phosphate of lime, one analysis showing over 16%.¹ Probably the basal part of the same layer would show less than one-tenth of one per cent. Silica is low, ranging commonly from 1 to 4%, both extremes being unusual. The iron and alumina usually comprise less than 1% of the rock.

Greater variation exists in the carbonate of lime and carbonate of magnesia, and as one increases the other decreases. In other words when one is high the other is low. The carbonate of lime is highest near the top and decreases irregularly with the depth. It may exceed 96% and fall to about 80%.

The carbonate of magnesia is lowest near the top, where it may be less than 1%, and highest near the base where it may exceed 16%. These relations are well shown in the two following analyses, the first of the "Gray Rock" near the top of the formation and the second of the "Six-foot Six" near the base:

Composition of "Gray-Rock."

	Per cent.
Carbonate of lime.....	96.51
Carbonate of magnesia	1.43
Silica	1.10
Iron and alumina.....	.70
Phosphorus	.04

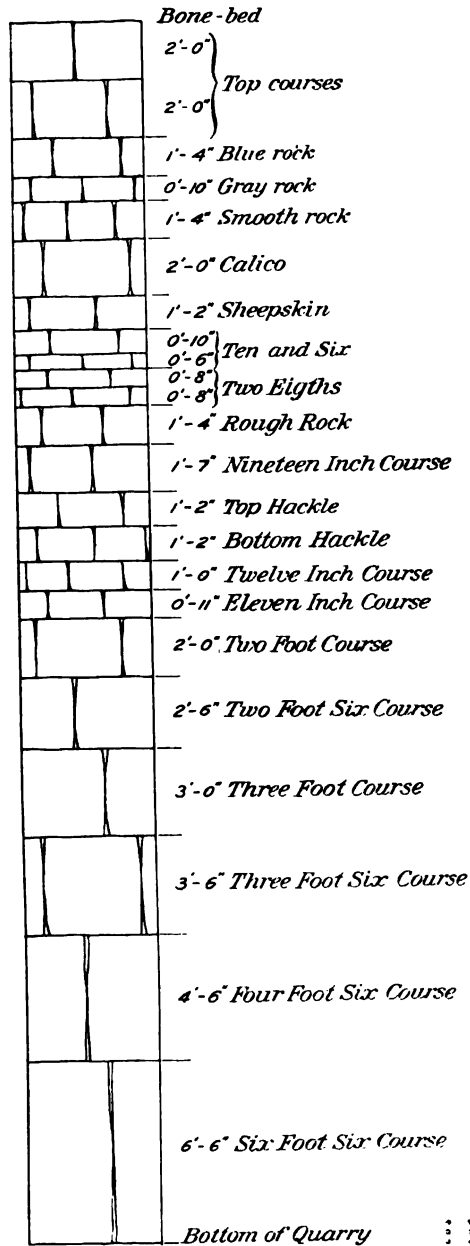
Composition of "Six-Foot Six."

	Per cent.
Carbonate of lime..	80.900
Carbonate of magnesia	16.070
Silica	2.000
Iron and alumina.....	1.100
Phosphorus	.016

Building Stone.—The formation has had an extensive use for

¹ Orton, Edward, Geol. Survey of Ohio, vol. 3, p. 611.

PLATE XXIV.



Section of Columbus limestone at Marble Cliff.

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buildings, the best known structures made from it being the State House and Judiciary Building. The former was erected more than a half century ago, and furnishes a good illustration of how the formation withstands the trying Ohio climate. The stone for this building was secured from the quarry just north of the State Hospital, the lower beds supplying the heavy courses for the walls and columns, and the higher beds, especially the "Sheepskin," for the steps. The Judiciary building, erected about fourteen years ago, is made from stone from the old Taylor and Bell quarry, just across the Scioto from Marble Cliff. Examination of the walls of the State House shows that the stone does not weather uniformly, the result being a rough surface. However, the formation is at its best in these massive structures.

The stone has been but little used in walls of residences owing to its unattractive appearance, but it has had an extensive market for foundations and door and window sills and caps. It is used in these ways in a large proportion of the residences and other structures of Columbus, its only rival being the Berea grit. The latter may be easily recognized by its more even layers and the limestone by its rougher surface. Further the limestone develops a slightly mottled surface on weathering, and the sandstone may have a light yellow or even yellow brown tint. A little practice makes it easy to distinguish between the two.

Practically the whole of the Columbus limestone may be used for building purposes. Naturally the thickest layers are best suited for massive structures while the thinner beds serve for caps, sills and steps in ordinary structures. The layers do not vary greatly in a physical way, so that one works about as easily as another. The stone does not carve well. In former years it had a market for curbings and flaggings, but this is now supplied by sandstone and concrete. It has been used also for pavements.

All in all the formation cannot be classed as a first rate building stone, except perhaps for massive structures, its appearance being unattractive, and it is gradually being discarded except for foundations.

In Making Pig Iron.—The great demand for the stone is for this purpose. It unites with the silica of the iron ore and the ash of the coke, forming a fusible slag which is drawn from the furnace at regular periods. For use in making pig iron the limestone must be low in phosphorus because that element makes the iron brittle. Silica and sulphur also should be low. Not all of the beds can be used for this purpose, and at present the upper limit is the "Gray Rock." All below this layer is available, though some beds are better adapted than others. The demand for the Columbus limestone for making pig iron is very large and bids fair to continue so many years. At present the market extends as far as Wheeling, Cleveland, Cincinnati and Ironton.

Other Uses.—The stone has a small market at Barberton where it is used in making soda ash. When ground to a powder it is a constituent in glass manufacture. A smaller use is for fertilizing, serving to neutralize the excess of acids in certain soils and to supply lime in others. Pieces that cannot be used for other purposes are crushed for ballast on railroads, for concrete and for making roads and walks.

Formerly it was extensively burned for lime and the last of the old kilns at Marble Cliff has recently been torn down. In fact it is still occasionally burned in a very small way at Dublin. The stone makes a good lime and the decline of the industry is due in part to the sharp competition of other localities, but more largely to the fact that the stone can be used with more profit in other lines.

The Delaware Limestone.

While in other parts of the State this stone may be classed as a limestone, in the territory near Columbus it is represented by shales. These have to be removed to reach the Columbus limestone, and being unsuitable for other purposes are crushed and sold for ballast, road-making, walks and concrete. The Pennsylvania Railroad uses it for ballast as far east as Pittsburgh and west to the Indiana line.

The Berea Grit.

As the Areal map shows, the Berea grit outcrops across the eastern part of the territory, along a north and south belt. The formation is drift covered, but exposures are found along streams. It is of very little importance and is nowhere worked regularly. At the village Harlem the stone has been quarried in recent years for road making. It is crushed and covered with a layer of limestone, but is soft and crumbly and does not make a good road, even when covered with better material.

A few pieces of stone are occasionally taken out for building purposes along Rocky Fork near Gahanna, and the presence of an old pit at that place suggests that it was formerly worked in a little more pretentious way.

The Cuyahoga Formation.

This formation, which underlies the eastern part of the area, contains a few layers of sandstone. It is of very little importance, but is worked with some regularity in two quarries. One of these is at Lithopolis where the stone is said to have been quarried in a small way forty years. The principal stratum measures nearly four feet in thickness and a little higher is one of two feet. The remainder of the stone in the

quarry is of little or no value. The two layers are worked in large blocks, hauled on wagons to Canal Winchester and then shipped to Columbus where they are sawed to desired sizes and used in door sills and window caps. The available supply, however, has been largely worked out. It has a light color and is of good quality.

The other quarry is near Reynoldsburg and has been worked many years. The quality is similar to that at Lithopolis, and the supply is larger. The desirable layers range from 3 to 48 inches in thickness, and are separated by beds of shales that vary ordinarily from one to five inches. The total thickness of the workable stone and included shales is about 18 feet, but this may vary from place to place. Nearly the whole output is sawed into pieces of suitable sizes and hauled to Columbus. It is used for flagging and for purposes similar to that from Lithopolis. The stone is reported to have been used for culverts and bridges in building the National Road.

Years ago the stone was quarried along the creek just east of Black Lick station. It generally occurs in thin even beds, but sometimes this character is wanting. Often the grains of sand are not strongly cemented, and the rather large proportion of clay present absorbs water which may cause cracking on freezing. The layers vary much in value, the best being of fair grade and the poorer worthless. They are often separated by beds of shale which increase the expense of quarrying. The stone forms the walls of the Institution for the Blind at Columbus and has been used in many other structures.

CLAYS.

The term clay is rather loosely used. Popularly it refers to the fine material found nearly everywhere on the earth's surface. Since, however, shales are in most cases simply mud that was deposited under water and then more or less solidified, they too are often classed with clays. Strictly speaking clays consist of kaolin mixed with various substances such as silica, silicates, carbonates, oxides and hydrates. Kaolin is formed in the main by the decay of feldspar which is a common mineral in granite and many other igneous rocks. Pure kaolin is not often found in large quantities, but when mixed with the various materials just referred to, it almost covers the earth's surface.

The nature and quantity of materials mixed with kaolin have an important effect on the clay. Thus iron colors it, and when the clay is burned gives a characteristic red which grows darker and may become black if the heat is sufficiently high. If the iron present is very small the clay may burn buff, and the same color results when lime is abundant, since it serves as a bleaching agent. The iron, magnesia, potash and lime (known as fluxes) lower the melting point of clay. The best fire clay is a variety having but little of these substances and so fuses

only at a very high temperature. This variety is commonly found underlying coal seams for the reason that the vegetation of which the coal was made removed the iron, magnesia, lime and potash contained in the clay, thus changing it to fire clay. Clays high in kaolin and low in other minerals are used in the manufacture of the finer wares such as pottery, while the more common varieties serve for bricks, tile and sewer-pipe. The clays found in the territory included in this bulletin are all of low grade, and occur at three horizons as follows:

Ohio Shales.—These extend across the middle of the territory from north to south and are inexhaustible in quantity. Fine exposures may be seen at many places, notably along the Olentangy River and many of the small tributaries to it.

While these shales may be used for the more common products such as bricks, drain-tile and sewer-pipe, they are not well adapted for any. The composition may vary rapidly in vertical section and areally, making the product hard to control in the kiln and the result uncertain.

Frequently considerable carbon is present, the residue of marine plants of the Devonian sea. The combustion of this, while the clay is burning, may, under certain conditions, produce too high a temperature, fusing the clay, and of course warping the tile or brick. Sulphur also is present in varying quantity, and sometimes concretions of pyrites (sulphide of iron) are common. The effect of sulphur depends quite largely on its condition, that is, whether it is free or combined with other elements. Often it appears on the surface of the finished product as a white coating that is unsightly and of course injures the sale.

Calcium carbonate is another substance that is nearly always if not always present. In certain layers this may comprise a large part of the mass while in others it may be very small or possibly wanting. The effects of this are various, depending in part on the proportion and on the other substances present. It may promote fluxing, and if abundant acts as a bleaching agent, so that the product has a buff color.

The iron present is in the form of carbonate, sulphide and oxide, and the proportion of these varies notably in different parts of the shales. Iron promotes fusion and influences the color. The latter, however, is not dependent entirely on the amount of iron, but also on the form in which it exists, the other substances present, the degree of heat, and the physical state of the clay.

These shales were formerly used in a large way at North Columbus in the manufacture of sewer pipe. The plant was established about 1869 and soon became a large producer. The market extended from Maine to Mexico, and it is said that sewer pipe from this factory was laid in every state east of the Mississippi River. The shales were ground and moistened and then moulded into the desired shapes and



A.—Brick yard at Taylors.



B.—Artesian well near Harrisburg.



sizes. The material shrank greatly on drying and burning, making it difficult to keep the larger sizes in shape. Salt and manganese oxide were thrown in the kiln, the former for a glaze and the latter to give the product a dark color. In 1900 the plant was sold to the American Sewer Pipe Company which operated it a short time and then for business reasons closed it. Later the plant was leased to a brick company which ran it for a short period.

The plant of the Fish Pressed Brick Company was located at the intersection of East Fifth Avenue and the Big Four tracks. For many years its product found a large market both at home and at more distant places. Financial difficulties finally closed the works. Products made from these shales burn to a light red, but a higher temperature darkens the shade somewhat.

Bedford Shales.—These outcrop as a rather narrow strip along the eastern border of the Ohio shales. Exposures are much less common, but the dark red color makes them conspicuous. At present these shales are used for bricks or drain-tile at two places, Canal Winchester and Taylors. At the former the use is so small as to be hardly worth mentioning, but the two plants at Taylors are more important. The bricks are used in buildings, sewers and to a small extent for paving. Only the more common varieties are made.

Glacial Drift.—This covers practically the whole area and is often suitable for common bricks and drain-tile. The latter is made at many places, in truth "too numerous to mention." Brick kilns also are found. Probably the largest plant of this sort is at Groveport where a clay from the valley of Big Walnut Creek is used. This gives a color that ranges from light red to black and the product finds a market as far distant as New York. A plant at Westerville has been in continuous operation since 1876, making at present building bricks and blocks and drain-tile. A clay from the valley of Alum Creek is used.

From what has been stated it is clear that the territory considered in this bulletin contains a vast quantity of clay that may serve in the manufacture of the most common products, though the output at present is small.

SAND AND GRAVEL.

Large deposits of these are not widely distributed in the vicinity of Columbus. Especially is this true of the northern half of the territory. Farther south sand and gravel are more abundant. They occur in the valleys and channels of streams, and also outside of them. All of these deposits are due quite largely to glacial and fluvio glacial action. In the valleys the glacial materials have been worked over by running water, but outside they usually lie as the glacier or glacial waters left them. Generally the sands and gravels are distinctly stratified.

A large deposit of gravel is found on the east side of Walnut Creek, where the Columbus Buckeye Lake and Newark traction-line crosses, and has been extensively used in road building by that company. Baker's Hill, south of Columbus, is essentially a mass of sand and gravel. Much of it has been used by the Scioto Valley traction company in making the fill near Obetz Junction. Other hills of these materials are found on the Hartman farm south of Columbus.

Within the past few years a unique industry has developed at Columbus. This consists of dredging the channel of the Scioto for sand and gravel. Two styles of dredges are used. One lifts the materials in buckets while the other sucks it up. Once on board the dredge, the material is screened, the finer forming sand and the coarser gravel. Boulders secured in the process are crushed and mixed with the gravel.

It might be expected that the sand and gravel removed in this way from the bed of the river would be replaced promptly by high water. This is quite true, but the substance is mud, showing that the Scioto transports only fine material in this locality. Above the city this river flows over bed-rock. Possibly large beds of sand and gravel may be found in the channel below the city.

The valley of the Scioto from Columbus south contains in places important deposits of gravel. These are at present worked at one or more points on the west side of Columbus. Probably many residences in that part of the city stand on beds of this material.

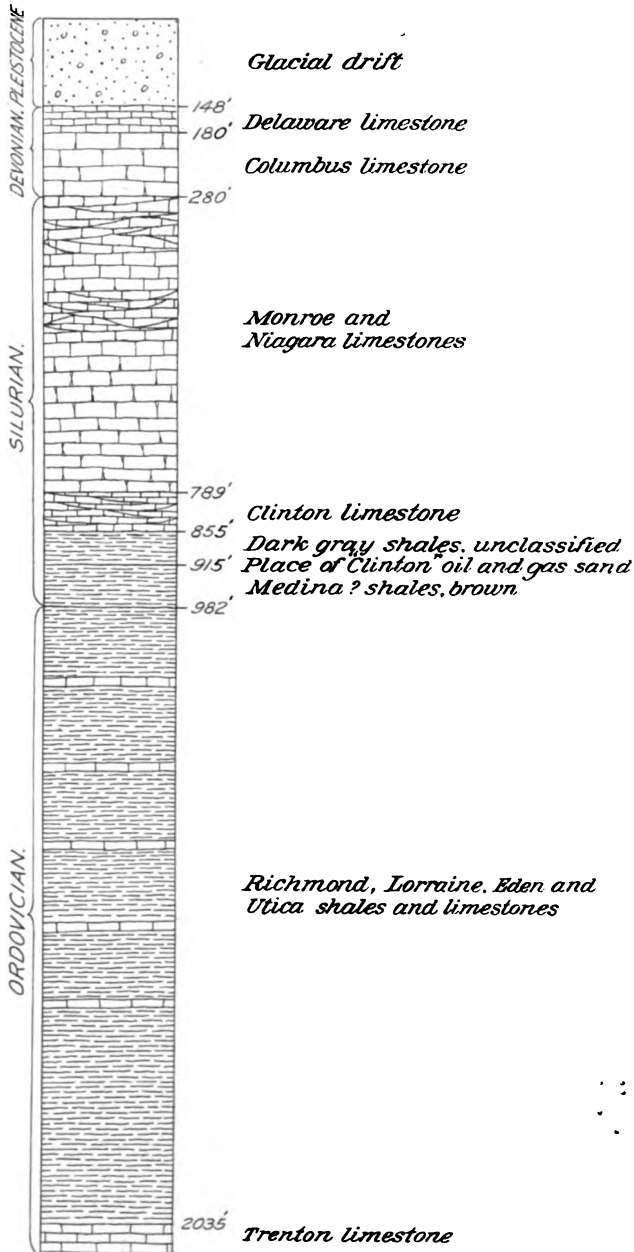
The uses of sand and gravel are well known. Probably the most extensive one of gravel is road building, but it is used also in making walks, in concrete and in certain kinds of roofing when tar is used and protected with a light cover of gravel. Sand has a large demand for making plaster and in cement work.

Where gravel is lacking the farmers are much handicapped in building good roads. Northwest of the city, crushed limestone from the quarries along the Scioto is used, but to the northeast this is lacking. As might be expected, the roads there are poor, but within the past few years the farmers have begun building pikes with crushed stone. This is commonly sandstone in part, obtained in nearby quarries and is covered with limestone from the Scioto Valley.

SEARCH FOR OIL AND GAS.

The discovery of natural gas in the Trenton limestone at Findlay in 1884 and of oil a year later encouraged drilling in many parts of the State. Columbus citizens were quick to see the benefits that would result from the discovery of oil or gas, and in 1886 drilled a test well in the valley of the Olentangy near Buttles Avenue. The stratum sought was the Trenton limestone which was yielding such surprising results in Northwestern Ohio. This was reached at a depth of 1,915 feet and drilling ceased at 2,020. Not a trace of either fuel was found.

PLATE XXVI.



Section of the Kilbourne & Jacobs well, Columbus.



Not satisfied with this test, the Kilbourne & Jacobs Company drilled a well on their grounds in 1891, the object being a supply of natural gas for their shops. The Trenton was reached at a depth of about 2,027 feet, but contained neither oil nor gas. A record of this well, showing the formations drilled through and their thickness, may be seen on Plate XXVI.

While these wells are the only ones drilled in Columbus for oil or gas, neither was the pioneer. Many years ago (1857-1860) a well was sunk on the State House grounds to secure an adequate supply of pure water for the Capitol. The drill did not come to rest until it had reached a depth of 2,775 feet. This well too was a failure, for at a depth of 180 feet sulphur water was found, and at 675 feet a brine.¹ The Trenton was shown to be 475 feet thick and below this was found 316 feet of white sand-rock.

The deepest well drilled in the vicinity of Columbus was on the Hartman farm south of the city. It reached the unusual depth of more than 3,100 feet, but like the rest was a failure.

About 1896 a determined effort was made to secure oil or gas in the valley of Big Darby near Harrisburg. Three wells were sunk, each reaching a depth reported at about 1,680 feet. Like most wells drilled at that time, the objective rock was the Trenton which should be found at a depth approximating 1,825 feet. At depths reported from 388 to 400 feet a large supply of fresh water was secured which still flows to the surface. (Page 124.)

Some years ago a well was drilled on the Rohr farm in Madison Township near the junction of Alum and Big Walnut creeks. The Trenton limestone was struck at 2,140 feet, but work continued until a depth of 2,675 had been reached. Neither oil nor gas was secured. A test was made in the valley of Alum Creek about three miles northeast of Linden. The Trenton was reported at 2,170 feet and the drill was kept at work until the formation had been penetrated to a depth of 159 feet. The failure of the well was complete. About the same time a well was drilled on the William Morrison farm, one mile east of Blacklick. It reached a depth of 2,153 feet ending in the red shales called Medina. The "Clinton" sandstone was absent, its place being occupied by shales. Neither oil nor gas was found.

Early in 1911 a well was completed in the extreme southwest corner of Mifflin Township near the northeastern corner of Columbus. The top of the Devonian limestone was found at 274 feet and the base of the Clinton limestone at 853. The Trenton was struck at 2,110 feet and the drill was kept at work until a total depth of 2,630 feet was reached, but neither oil nor gas was found.

In 1909 a well was sunk to the horizon of the "Clinton" sand-

¹ Orton, Edward, Geol. Surv. of Ohio, vol. 6, pp. 107, 108; also, vol. 1, pp. 113, 114.

stone in the valley of Little Walnut Creek near Canal Winchester, but the desired rock was absent and the well was a total failure. About the same time a test was made on the Oyler farm a short distance southwest of Lithopolis, the result being similar to that near Canal Winchester.

Other wells were drilled many years ago in search of oil and gas, but the records have been lost. Among the places where tests were made may be mentioned Canal Winchester, Westerville and Sunbury. Probably all these reached the Trenton limestone. The numerous wells drilled on the territory included in this bulletin seem to demonstrate that oil or gas in commercial quantity is wanting.

It may be worth mentioning that the rock from which gas in great quantity is secured in central Ohio is absent in the Columbus territory, its place being taken by shales. The gas is derived from a bed of light colored sandstone about 25 feet in thickness. The position of this rock varies from about 105 to 200 feet below the Clinton limestone, and it is covered and underlain with shales. It is commonly called the Clinton sand, but its age has not been definitely determined. The location of the deep wells in the vicinity of Columbus is shown on the map. (Plate XXVII.)

The absence of the Clinton sandstone explains why oil and gas are not found in that formation, but the reason for failure in the Trenton is unknown. It may be due to smallness of porosity or to the absence of folds or anticlines which many think are essential to these fuels in large quantity. Possibly the failure may be a result of unsuitable conditions for preserving the life of the Trenton or to the formation of oil or gas from it.

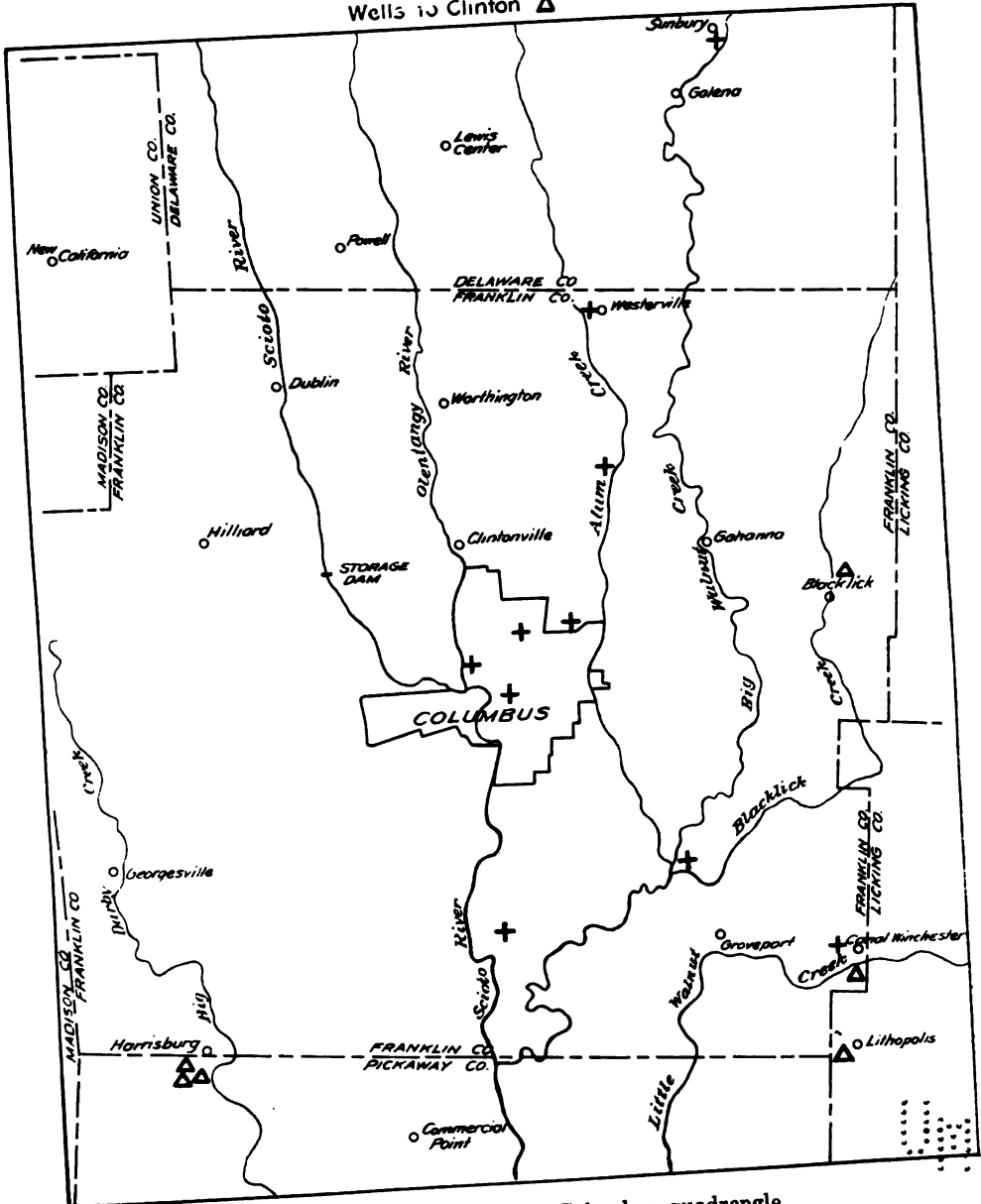
UNDERGROUND WATERS.

These depend chiefly on the precipitation in the form of rain and snow, nature and thickness of the surface material or mantle rock, and the porosity and structure of the bed-rock.

The importance of precipitation is self-evident and so will not be discussed here. The quantity of water that may be stored in the mantle rock depends on its thickness and its porosity. When the mantle rock is of fine material like clay, the porosity is small and little water can be stored. In fact such material is sometimes quite impervious; but when it consists of coarser materials and especially when it contains much sand or gravel the porosity is large and the quantity of water that may be stored is in proportion. It is apparent therefore that the amount of water that may be found in the mantle rock varies from place to place. Especially is this true in drift covered areas where the texture changes rapidly.

Much the same may be said of the bed-rock. It may be porous and capable of storing a large amount of water or it may be fine and

KEY
Wells to Trenton +
Wells to Clinton Δ



Deep wells drilled on the Columbus quadrangle.

24

quite impervious. Cracks, joints and bedding planes in the bed-rock are another factor, for they too may serve to store the water. Our territory well serves to illustrate these points. Thus the limestones which underlie the western half of the area are porous and much broken by cracks and joints. Often these have been enlarged near the surface by solution. Further the bedding planes are well marked, making the formation as a whole capable of storing a large supply.

The shales, on the contrary, are fine grained and quite impervious. They are cut by many cracks and joints, but the faces of these fit closely. The bedding planes are innumerable, but so compact are the layers that there is little or no room for water. Manifestly large supplies cannot usually be secured from such rocks.

Underground water always contains mineral matter in solution. The nature and quantity of this is determined largely by the composition and solubility of the rock through which the water has flowed and in which it is stored. Thus on those tracts underlain with limestone the water contains much of that substance in solution and is "hard." This applies whether the well penetrates bed-rock or stops in the mantle rock, for the nature of the latter is commonly quite largely determined by the former. On the shale covered areas the water contains less mineral matter because the underlying rocks are less soluble. However, the glaciers left some limestone in the drift of those areas, and that of course modifies the water.

Iron is another common constituent of water. Usually it is in the form of ferrous carbonate (FeCO_3) and is not visible when the water first reaches the surface. The atmosphere rapidly oxidizes the iron to limonite ($2\text{Fe}_2\text{O}_3, 3\text{H}_2\text{O}$), an insoluble body of yellow brown color which settles to the bottom. In this form it is frequently seen along the channels of streams and on the beds of ponds. Sometimes the iron accumulates in this way in sufficient quantity to warrant mining and is known as bog ore, though no such deposits are found on the Columbus area. However, iron is commonly present in the springs and wells of this locality.

Occasionally water from springs and wells has the disagreeable odor of hydrogen sulphide. The source of this gas in such cases is not quite clear, but it probably results from the action of water on iron pyrites (FeS_2). The Ohio shales contain much of this mineral and it is on such areas that water with this odor is usually found. The best known springs of this kind in Ohio are at Delaware.

Wells.—Except in a few small areas, mostly along streams, the mantle rock has a depth adequate to hold a large volume of water, but often it is too compact. Wells in such places may give an inadequate supply and fail in time of drouth. Farmers meet the difficulty by digging deeper. The depth at which a satisfactory supply is found varies

greatly even where the surface is level or gently rolling. This results from the water bearing horizon rising or falling independently of the surface, as shown in Figure 16. Wells in the vicinity of Columbus commonly range from 15 to 50 feet in depth.

Quite often wells are drilled, the work being done by machines. Such wells are deeper and may penetrate the limestone where it lies immediately below the drift. They may exceed a hundred feet in depth

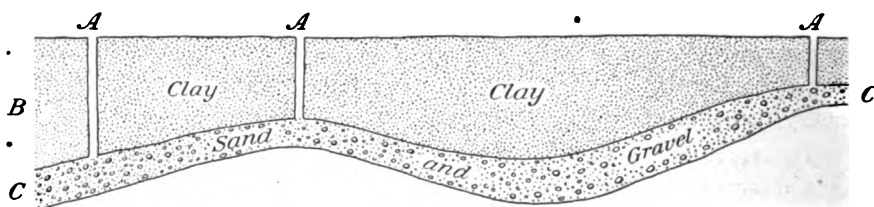


Fig. 16—Showing why the depth of wells varies on a flat surface. The letters A represent three wells. The bed of clay is fine grained and contains very little water, but the underlying bed of sand and gravel is porous and may be charged with water.

and usually give a large supply. Many wells of this kind exist in Columbus, supplying manufacturing plants or other industries requiring a large volume. Water obtained in this way is less likely to be contaminated with organic matter, but it is usually very "hard."

Artesian Wells.—A few artesian wells are found. Two fine ones may be seen just east of Harrisburg, one of them supplying the farm of the Columbus Hospital for the Feeble-minded. These wells were drilled for oil or gas (page 121), the supply of water being obtained at reported depths of from 388 to 400 feet. The artesian flow is due to the water bearing rocks rising to the west and being covered with an impervious layer of clay or shale. The water at depth is under "head" or pressure and flows to the surface wherever an opening is found. A precipitate of iron along the stream leading from the well indicates that the water contains some of that metal.

Near the corner of East 11th Avenue and Summit Street, Columbus, is another artesian area, but in the past few years so many wells have been drilled that the flow has weakened. The water was formerly found at a depth of a few feet and in several instances was encountered in digging cellars. Here the phenomenon seems to be restricted to the drift, but the general principle of "head" or pressure stated above holds.

Springs.—Springs are common, especially along the west side of the Scioto River where it cuts through the limestone, offering an outlet for the waters which have been stored in the rock. The Wyandot Spring, now submerged by the storage dam, is the best known of these. Tradition has it that Indians formerly camped in that locality on account of the water.

PLATE XXVIII.



The University spring.

10

The hills around Lithopolis have many springs, a few being large. The water-storing rock is mostly sandstone which is comparatively insoluble, and hence the water contains little mineral matter. One of the springs, "The Jefferson," is used in a commercial way; the water is bottled and shipped to Columbus where it is used for drinking purposes.

However, the most valuable spring on the area considered in this bulletin, is located on the grounds of the State University. A visit at almost any time, but preferably on a warm day, will show its popularity. Interesting too, it was a factor in determining the location of the University. After the generous offer of a large sum of money, made by Franklin County to secure the institution, had been accepted, various tracts were offered for sale to the trustees, and among them the Neil farm on which the University now stands. Naturally the trustees gave careful consideration to so important a question. After much discussion the situation was finally cleared by the remarks of a German-American member. "When at last he reached in his review the Neil farm, while extolling the character of the land as equal to any they had seen, he declared that 'dot sphring' settled the question for him." The trustees voted with the speaker, and so the University is by the spring.¹

About twenty years ago a sewer was constructed along the south edge of the lake and hence near the spring. It was supposed that the water feeding the spring came from the higher land to the north and hence would not be intercepted. However, the water flowed into the sewer and the spring went dry. Later the sewer was torn out and rebuilt in such a manner that water could not flow through its wall, and in consequence was compelled to resume its old course. Since that time the spring has pursued an unsteady way. The flow has varied greatly and occasionally has ceased. Lowering the lake level a few inches will stop the flow of the spring at once. This indicates that the sand and gravel underlying the valley and the lower part of its slopes are charged with water and whenever the level of the lake falls, that in the slopes likewise drops and may fall below the outlet of the spring. In the latter event it, of course, ceases flowing. The drift outside of the valley to the north, east and south contains much sand and gravel which stores a large volume of water, and this flowing toward the valley maintains the supply that feeds the spring.

SOILS.

Sources.—In an unglaciated region the character of the soil depends on the underlying bed-rock, for the soil was formed from it. Along streams, however, the soil may have been transported some distance, and so may show marked differences from the bed-rock.

¹ Address by Dr. Edward Orton. Twenty-fifth anniversary of the establishment of the University. Published by the University.

In glaciated regions the soil is derived partly from the underlying rocks, but more largely from those a short distance in the direction from which the ice came, and to a much smaller extent from more distant places. Thus the soils in the area discussed in this bulletin, being glacial, have been formed largely from the limestones, shales and sandstones which underlie the area, but they contain materials from the counties to the north and to a much less extent from the territory north of the Great Lakes.

As has been shown in Chapter I, the bed-rocks in this vicinity form usually rather narrow strips that extend north and south. The glacier in this territory moved south, and hence the soil of any locality is much the same as if it had been formed from rocks just below, and had added to it materials from the comparatively distant north. In other words, where the bed-rock is a limestone, it is usually overlain with a limestone soil; and where it is a shale, it is covered with a shale soil. However, along or near the line of junction of the shales and limestones, the soils may contain materials derived from each.

Varieties.—The soils of this area consist of loams, that is, clays containing sand or gravel. Depending on the proportions of these the following varieties are recognized:

Soil.	Square miles.
Miami clay loam.....	767
Miami black clay loam	72
Miami loam.....	71
Miami gravelly loam	35

These form irregular patches so that when they are shown by different tints, the map has somewhat the appearance of "Joseph's Coat." These variations result from glacial deposition and the work of streams.¹

As shown above, the Miami clay loam is by far the most abundant. In fact, it covers the entire area, except along streams and numerous but usually small patches on the uplands. Its value is not uniform, for it is dependent in large part on the bed-rock, as will be explained later.

The Miami black clay loam differs from the preceding variety chiefly in its color. Nearly always it is found on tracts a little lower than the surrounding land. Its color is due to an accumulation of vegetable matter which in part grew on it and in part was carried from the higher land, wind and water serving as the transporting agents. Such tracts are usually small and are most abundant in the southern half of the territory. When drained, they are more fertile than the surrounding Miami clay loam.

The Miami loam is of finer texture than the preceding varieties.

¹ For maps, see Bureau of Soils, U. S. Dept. of Agriculture, 1902 and 1905.

In other words, it contains more material like silt and clay. It is found in valleys and so forms narrow strips, the widest being along the Scioto south of Columbus. It is a deposit made by streams, and usually overlies a bed of gravel. The dark color is due to the presence of vegetable matter scattered through it. As a rule it is very fertile.

The Miami gravelly loam, as its name indicates, contains pebbles or gravel, but the percentage of this need not be large. Such areas are found along or near streams and sometimes form the second bottoms or terraces. They are largely the work of glacial waters, and are more extensive on the southern half of the territory.

Fertility.—The classification just given is based almost entirely on fineness of grain. Fertility, however, is not wholly dependent on the physical state. It is modified to no small extent by the chemical composition, which in turn depends (1) on the rock from which it was derived, and (2) on the organic matter present.

Considered from the standpoint of bulk, soils consist largely of clay and sand, but these alone would not support vegetation. In fact it can scarcely be regarded as settled just what is necessary to form a soil, but most authorities include lime, magnesia, iron, potash, sulphuric and phosphoric acids.

Soils formed from limestones are usually more fertile than those from shales or sandstones, because the rock and hence the soil is richer in the essentials to plant growth. Practically all limestones contain both lime and magnesia. The iron present may be in the form of the sulphide and this on decomposition may yield iron and sulphuric acid. Another common constituent, though usually in small quantity, is calcium phosphate and this supplies the phosphoric acid.

As a rule the limestone soils of Ohio are notably richer than those formed from sandstones and shales. This is best shown in those parts that were not glaciated, the farmer stating with pride that "my land is of limestone origin." It is also demonstrated by the glaciated parts of the State, for the western half which is underlain with limestones is much more fertile than the northeastern, which has a floor of shales and sandstones.

It is unnecessary, however, to go so far from home for illustrations of this kind. Thus a large part of the western half of the territory discussed in this bulletin has a limestone floor while the remaining portion is underlain with shales or sandstone. Usually a single trip will show the superiority of the soils in the former area. This is best shown by crops which require a strong soil, such as corn.

Eastward from the Scioto River the bed-rock is largely shales which have yielded a soil poorer in plant food. Besides it is fine grained and does not freely permit of atmospheric circulation or the escape of an excess of water, such as is present in springtime or after heavy rains.

In times of drouth the soil is hard. The best examples are found in the northeastern part of the territory.

The production of the soil in such places would be notably augmented by draining. This may be in the form of open trenches, or better of tiling or of both. Two farms, side by side, one well drained the other not, give very different results, especially during a wet season. Probably no one thing would so greatly increase the productiveness of such areas as draining. It is expensive, but the yield more than compensates.

In the southeastern quarter of the territory, that is from Columbus to Greencastle, the character of the soil has been modified more by the glacier than in the area referred to in the last paragraph. The soils contain more sand and gravel, and in places are of superior quality.

The valleys, as might be expected, are more fertile than the upland. Their soils contain more sand and gravel, and hence have better natural drainage and work more readily. In addition they appear to be richer in plant food, having a larger variety of minerals and also more organic matter. Much of these may have washed from the adjacent uplands. In fact this transfer is the principal reason for the general superiority of valley soils.

These soils are a valuable asset of the Columbus territory. The Scioto Valley south of the city has a maximum width of a mile, but north of the city it is much smaller. The valley of Big Darby in the vicinity of Harrisburg varies from one-half to three-quarters of a mile in cross section, but is much narrower to the north. The third important valley in the western half of the territory is that of the Olentangy, whose width usually ranges from a quarter to a half mile. The soils of these are of marked fertility and are especially well adapted for corn and alfalfa. Probably those parts near the city will be more largely used in the near future for gardening.

On the eastern half of the territory the valleys are smaller and on the average less fertile, the soils having been derived more largely from shales. The valley of Alum Creek varies from a quarter to a half mile in width and that of Big Walnut averages less, except below its junction with Alum and Blacklick Creeks, where it is wider and notably fertile. The valleys of Blacklick and Little Walnut are still narrower. That of the latter has a rich soil and yields large returns, especially from corn.

All the valleys in the territory covered by this bulletin are subject to overflow and the damage to farmers resulting therefrom is sometimes large. The control of these floods is attempted by levees, but the result has been only partially successful. Sometimes the waters leave a deposit of material that adds to the fertility. At other times sand and gravel are deposited. Occasionally the waters erode and then may sweep away the soil.

As a summary it may be stated that the soils are fertile but vary

from place to place; that those overlying the limestones are generally richer than those over shales, and that those in the southern half of the territory are better than those in the northern half.

AGRICULTURE.

Outside of Columbus, agriculture is the principal industry. General farming is practiced, but the numerous branches of this vary somewhat in importance in different localities. Thus in the northeastern quarter, the clay soils are best adapted to grazing, and dairying is an important industry. Nearly every village has a creamery and Sunbury a fine one. This phase of the industry is practiced in other areas, but is less important. Columbus is an excellent market for these products.

Except in the northeastern quarter, corn is the principal product of the farms. The rich soils are well adapted to this grain and yield excellent results. The broad valley of the Scioto River south of Columbus is perhaps unsurpassed in the State for this crop. Wheat and oats also are extensively grown, especially on the upland. On the northeastern quarter these grains do better than corn, and with dairying, form the principal industry of the farmers. The southeastern quarter also is a large grower of wheat and oats, these grains dividing honors with corn. The soils in this area vary considerably in fertility, corn flourishing in the richer parts, wheat and oats in nearly all.

With so good a market gardening is naturally an important industry, though the soil cannot be regarded first class for this, being usually too clayey and hard to work. The largest gardens are found south and southeast of Columbus, and also in the valley of the Olentangy from Third Avenue to the northern limit of the city.

The hills in the vicinity of Lithopolis are comparatively poor and not well adapted to grains, especially corn. They yield excellent results, however, with fruits. Berries are extensively grown and to a lesser extent, the larger fruits. The soils are suitable, and the high land gives excellent water and air drainage. Late spring frosts are not common because the cold heavy air slips down the hillsides on the lower tracts. The land along the Olentangy north of Columbus is also well adapted to fruits. The industry there has only been started, but should grow in importance.

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